FIRST STEPS

IN

ELECTRICITY

DESIGNED FOR THE ENTERTAINMENT
AND INSTRUCTION OF YOUNG PEOPLE AT HOME
AND IN SCHOOL.

BY

CHARLES BARNARD

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PUBLISHERS' NOTICE.

For the convenience of those who cannot readily obtain the different pieces of apparatus mentioned in this book, the publishers have prepared an Electrical Outfit comprising most of the articles used in performing the experiments described, which they will send by mail, securely boxed and postpaid, for $1.50. A circular, descriptive of this outfit, will be sent free on application. The more elaborate and expensive apparatus may be obtained from any of the dealers in electrical goods.

PREFATORY NOTE.

The aim of this book is to describe a number of simple and inexpensive experiments in electricity that can be performed in schools, the lecture-room, and the home circle. None of the experiments are at all difficult or dangerous, nor are the materials, if used with ordinary care, likely to do the slightest harm to furniture or clothing. The aim is also to enable the reader to obtain a general idea of the laws governing the manifestations of this force in nature, and to see how this force is used in the arts, in business, and in manufactures. It is the hope of the author that the book may be of use as a school reader, as a guide to home amusements in science for winter evenings, and as a help to all who wish to get a notion of the general principles underlying the great modern inventions in electricity.

CHARLES BARNARD.

NEW ROCHELLE, N. Y., *March, 1891.*

CONTENTS.

FIRST STEPS IN ELECTRICITY.

CHAPTER I.

ASKING QUESTIONS OF NATURE. FRICTION AND ELECTRICITY. ATTRACTION AND CONDUCTION.

The afternoon is warm and sultry. There are dazzling mountainous clouds built high in the blue sky. In the west the billowy masses seem duller and take on tints of pale red in the hazy air. There is a movement among these sierras in the west, and they mount higher and shut out the sun. There are darker shadows below. A vast arch of greenish gray clouds, ragged and torn, creeps up the sky, and behind it is an ashen veil of rain. From the threatening clouds leap flashes of light. Suddenly there seems a more vivid flash and a tall tree is split open and falls to the ground, while terrible peals of crashing thunder fill the air and drown the roar of the wind and the shrill soprano of the rain sweeping through the woods or

whitening the water in the river. After the shower has passed we go out and inspect the fallen tree. It is shattered and torn as if struck some terrible blow.

A young girl combing her long hair in a cold room on a frosty morning hears soft crackling sounds in her hair as her comb slips through her tresses.

A woman going out for a walk on a cold day sees some lint on her dress and tries to brush or pull it off and finds that, for some reason, it clings to the fabric. A bit of feather floating near her dress seems to be bewitched and flies through the air and sticks to it as if it were warm wax.

Some children playing with a cat in a dusky room on a winter's night see tiny flashes of light in the cat's fur. Every stroke of affection they bestow on the cat's back is rewarded with a touch of fire.

Here are four curious things you have, perhaps, seen many times. We say they are natural phenomena. What do they mean, are they in any way related to each other? Why did they appear? Now there are three steps you can take. You can ask some one about them, you can find a book that will tell you some facts concerning them, or you can examine the phenomena for yourself and find out by asking questions of nature. It is a good idea to ask people to ex-

plain things and it is not difficult to sit in a comfortable chair and read a book. It is far pleasanter and every way better to find out for yourself.

All things—plants, animals and inanimate objects, planets, stars, grains of dust in the road and star-dust in the sky—behave in a certain way under certain circumstances. The behavior of anything is the result of some law, and this behavior shows what the law is. A heavy book in the hand, if let fall, drops upon the ground. It behaves in that particular manner because there is a law that it should fall unless supported. The law of gravity caused the book to behave in that way, and its behavior is evidence of the law. Try this again. Try it many times, and the result is the same. We are compelled to think there is a law governing the book's fall.

Take a light feather out of doors in the wind, and let it fall. It floats away, perhaps out of sight, without falling. Here seems to be an exception to the law. Get another feather and try it again in a closed room. It flutters to the floor. There is no exception and we conclude that the feather floating away on the wind behaved in that manner because controlled by some other law that, for the time, was stronger than the law of gravitation.

We have performed an experiment. By means of the book and the feathers we asked questions of nature.

We placed them under certain circumstances, and by watching their behavior, learned something of the laws governing them. We cannot call this hard work, for the experiment was interesting and it was only a pleasure to make it. The search for knowledge of the world by means of experiment is one of the greatest pleasures you can have, and you will find that this method of getting at facts in nature is quite as useful as asking questions of people or reading good books. All that is known of nature and her laws was found out by experiment, by studying the behavior of common things.

Suppose the children, wishing to see the curious sparks on the cat's back at another time, had taken her into a warm, well lighted kitchen, or out of doors on a summer day and then repeated the experiment. They would be disappointed. Not a spark would appear. They would really be repeating the experiment under different circumstances and the result would not be the same. They might imagine that the sparks were made by the cat, but would at once wonder if she did it, why she could not be good enough to let off her little fire-works at one time as well as another. If they were wise children they would not make this mistake, and would conclude that the experiment had been performed under different circumstances and that

therefore the sparks behaved in a different way and refused to appear. Plainly, the children would really begin to learn something about this matter. They would see that the phenomenon appeared only in a cold dark room and not in a warm light one. It is evident that this method of hunting for facts with a common thing like a cat is a very pleasant way of studying nature. The children did not find much, yet it was really something, for they proved that light and heat in some way affected the sparks observed in the cat's fur. They also proved, incidentally, that the cat herself had no hand in this sparking business.

You can study these four phenomena and many others equally curious by simply experimenting or asking questions of nature. It is our plan to now do this by actually performing experiments and by a little reading to try and understand what the experiments mean. All you need is a willingness to learn and patience. Do not be afraid to try many times over. Do everything slowly and thoroughly. Remember always that while nature is dumb, she never makes mistakes. Keep full and complete notes of all you do. Have a pad and stylographic pen handy at all times and record everything you do or see at the time the experiment is made. Shall we now go on ?

For the experiments we are to perform, we need first

a suitable time and place, and secondly certain simple tools and apparatus. For all the experiments the best time is the evening and in winter. Cold dry weather is better than warm or damp weather. If the experiments are performed in the daytime choose a sunny day in preference to a cloudy day. The best place is a warm, dry room where there is an open fire. In the daytime select a room with sunny windows. In all the first experiments there must be some means of warming our apparatus, either by placing them before a fire or in the sunshine.

The best table for our work is a common wooden one, and for a cover use brown wrapping paper or place on the table a pine board, smooth and dry. On this board or on the wrapping paper, place all the apparatus used in the experiments. Take particular pains to see that the board and the paper are dry, and to make sure hold them to the fire just before you begin your work.

Next we shall need about a quarter of a yard of good silk—any remnant of dress goods will answer. Cut this into pieces six inches square, and placing one over the other stich them together to form a pad or holder. Pull out or unravel from the silk or from a ribbon or any fabric a few light pieces of yarn or ravellings.

Get also a small piece of loose cotton batting. From the dealer in painters' materials get a leaf

or two of a thin foil (like gold leaf) made of an alloy called Dutch metal. If a leaf cannot be procured, buy a whole "book" which is the name given to a little package of the foil. Next, we need a glass tube of some kind. The chimney of a student lamp will answer: a rod or stout tube about half an inch in diameter and eighteen inches long is much better and and is very cheap. Pull from the cotton batting a couple of little tufts and cut from the Dutch metal foil several pieces half an inch square. See that the glass and the silk are clean, and then, having warmed all these materials before the fire, place them on a dry board on the table.

Nothing whatever happens. None of the things seem to have the slightest influence upon each other. Putting these things close to each other does not produce any change or effect of any kind. Now take the tube and pad to the fire and make them quite hot. Then hold the tube in the right hand, and wrapping the pad about it, with the left rub the pad briskly along the tube for a moment or two. Now, on holding the tube over the things on the board, they behave in the most singular manner. They leap up to meet it and even cling closely to the glass. Take them off and repeat the experiment and they appear more animated than ever. Repeat the experiment in another way.

Let one person hold a tuft of cotton in the hand over the head and then drop it. As it floats on the air, let another bring the rubbed tube near it. The cotton behaves in the most surprising manner, leaping through the air to reach the tube.

Repeat the experiments several times, observing carefully everything that happens. Rest a moment and draw the tube through the hand. Now lay it upon the foil and threads, and nothing happens. Whatever the cause of the singular behavior of these things during our experiments it has now ceased to work and they are no longer drawn to the glass. The effects we observed have completely disappeared. Rub the glass again with the pad, and they all reappear.

We observe that the glass attracts the threads and foil only after it has been rubbed with silk, and that the attraction is but temporary. The rubbing with silk plainly excites this property in the glass, and for convenience, we will say the glass is excited after it has been rubbed by the silk. Excite the glass and try it on other light materials, paper, smoke, an empty egg shell, or on the hair of the head, and make a list of all the things you can procure which are attracted by the glass.

Procure a tumbler of the best quality of glass to be found, wipe it dry and place it upside down on the

board. Pull a bunch of fine threads (the filling) from a ribbon, twist them together at one end, and place the bunch on top of the tumbler with the loose ends hanging over the side, and lay a cent or other coin on it to keep it in place. Excite the glass and hold it before the threads, taking care to hold the part which has

No. I.

been rubbed opposite the threads. Instantly they will rise and stretch out towards the glass, every little filament standing apart from the others.

Picture No. I. shows how the threads behave when the glass is brought near them. Move the glass about, and the threads follow it as if alive. Brush the glass with the hand and repeat the experiment twice.

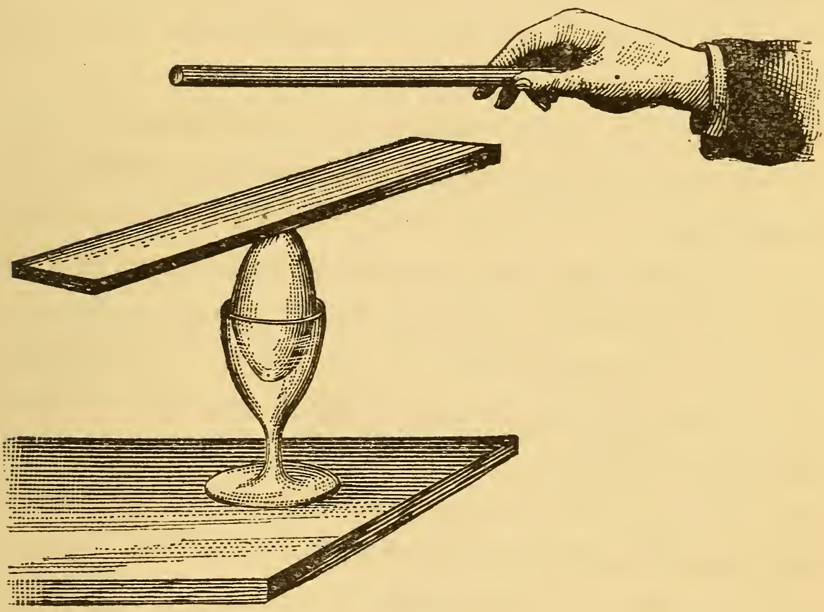
We have performed experiments which have been repeated many times for centuries. Long before the Christian era began men observed with wonder that if a substance called *electron,* and which we now know is yellow amber, be rubbed, that it has this power of attracting light bodies held near it. For centuries this could not be explained, nor can it be fully explained even now. We know nothing more than this: the behavior of these things is due to a certain force in nature which has received the name of *electricity.* It is easy to see where the name came from when we remember that these experiments were first performed with yellow amber or *electron.*

It is very difficult to say precisely what electricity is, and for the present we must leave the matter in suspense and wait till further experiments tell us more about it. For convenience we will say that these curious effects are produced by electricity and that we can produce these electrical effects by rubbing or friction. Already you see we have learned something from our experiments. You have discovered that when glass is rubbed with silk the glass is excited to electrical action, and when thus excited or electrified it will produce some very singular effects.

One more experiment. Procure an egg and an egg glass or small wineglass and set the egg upright in the

glass. Then get a slender pine stick about a foot long. A yard-stick can be used, if the pine stick is not handy. Carefully balance the stick on top of the egg as in Picture No. II.

Excite the glass and hold it beside the end of the



No. II.

balanced stick, and at once it swings round towards the glass. With a little practice it can be made to follow the glass round and round, clearly showing the stick is attracted by the excited glass.

You have now two facts—electricity can be excited by friction and this electricity has the power of at-

traction. By doing several experiments you plainly show that there is a law in the matter. Whatever behaves in a certain way every time it is placed in the same conditions we say is subject to a law. In this case we discover there is a law that electricity attracts. You have demonstrated the existence of electrical attraction, and as it repeats itself every time, we say there is a law of electrical attraction.

Having made one step in our work of discovery you can now use the knowledge thus gained to get still more knowledge. Let us use this knowledge to perform other experiments and see what new facts we can learn in regard to the behavior of things under the influence of electricity.

Rub the glass again and hold it over the tufts of ravellings on the tumbler, but quite high, say a yard or more over them. No effect. They do not appear to be affected while the glass is at that distance. Rub it and bring it slowly nearer the table, stopping at intervals to see when the attraction begins. It is plain that the electrical attraction does not extend very far from the glass. Try to be exact and make a note of the distance at which the attraction appears to begin.

Now let us try another experiment, using a part of the information you just gained. Get a piece of fine copper wire somewhat longer than the distance at which

you found the things began to be attracted. For instance, if the things began to fly up to the glass when it was six inches above them, make the wire not less than ten inches long. The best plan is to exceed the limit and the wire should be about eighteen inches

No. III.

long. Get a copper two-cent piece and suspend it from one end of the wire by twisting the wire round the coin. Then twist the other end of the wire round the end of the glass tube as shown in Picture No. III.

Carefully holding the tube in the hand rub it with the silk pad close up to the wire while the copper

coin is hanging by the wire in the air. Then hold the tube over the tumbler so that the cent on the end of the wire will be over the little bunch of ravellings. At once the threads are attracted towards the metal precisely as in our other experiments it was attracted to the glass. The tube is too far away to influence the threads, and we are obliged to think that in some strange fashion this power of attraction travelled down the wire to the coin and affected the ravellings, causing them to fly up precisely as in one of our other experiments. This is clearly shown in Picture No. III.

Repeat this experiment with other things and you will plainly see that all the effects of attraction take place near the coin on the end of the wire precisely as when you used the glass rod alone. Who first discovered by experiment that electron had this power of attraction is not known. It was observed by a number of people a long time ago, and yet not one of them seems to have tried to learn more or to have taken the little step in advance that you have just taken. It was not till quite modern times that it was learned that this power of attraction could be made to travel over a wire. Even then it was learned only by experiment. When in 1729 Stephen Grey discovered this curious property of electricity it was probably not known, and certainly was not mentioned in any book. He could

not, as people can now, read about it, and only by this very experiment you have just performed was he enabled to make this remarkable discovery. If it had not been known before, you, too, might have made yourself famous by its discovery. Stephen Grey fastened a long linen thread to a glass rod and hung it out the second story window of his house, and discovered that when the tube was rubbed the coin on the end of the thread attracted light substances on the ground below.

A good way to repeat the experiment is to fasten a long fine wire to the glass tube and hang it in the well of a staircase. Let one person hold and rub the tube, and let another go down-stairs and place the ravellings near the copper coin. Take pains that the wire is suspended clear of the stairs and that the experiment is done on a dry day when the glass and silk pad are warm and dry. This property which the copper wire and cent show is called *conduction.* We say electricity can be conducted and we call the wire a *conductor.*

CHAPTER II.

THE ELECTROSCOPE. CONDUCTORS AND INSULATORS. DU FAY'S EXPERIMENT. THE DANCING FEATHER. ATTRACTION AND REPULSION.

THE experiments you have performed have shown us three things concerning electricity. First it can be excited by friction or rubbing, as when you rubbed the glass tube with the silk pad. Friction caused it to appear and when it appeared we learned that it had the power of attracting light bodies. It attracts everything, but only the small, light materials we used showed it plainly enough for us to see and notice it. It can be conducted through copper, and copper is a conductor of electricity. Observe we have neither seen, heard, nor felt the electricity. We have seen only how it affects certain things and how it behaves when given a conductor. While we could not see it travel down the copper wire, we are very sure it did, because it produced the same effects at one end of the wire as at the other, though the wire might be many yards long. In other words your experiments have shown us the laws of electrical attraction and electrical conduction. Not

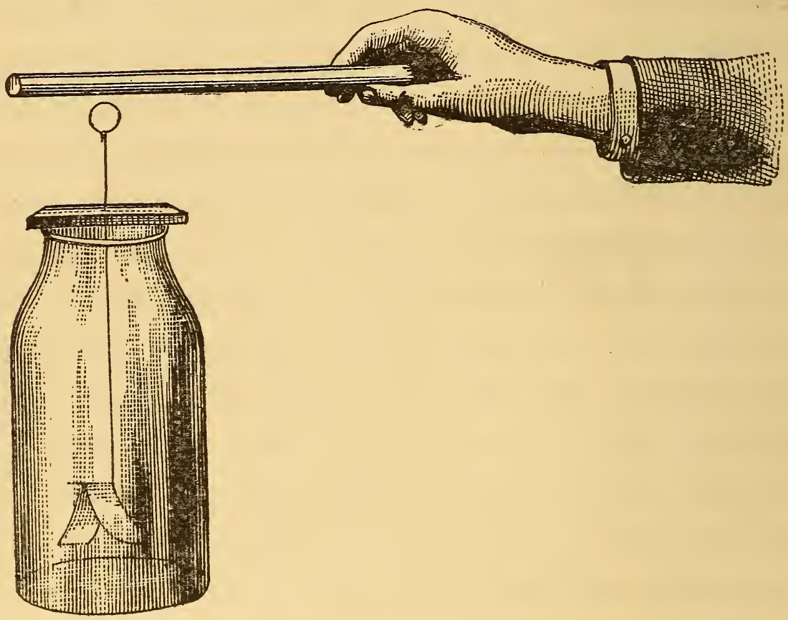
fully, because there may be much more to learn concerning these laws, but enough to prove that there are such laws.

We also noticed one other thing. When, after any experiment had been performed, the tube was drawn through the hand it lost all power of attraction. We must conclude from this that the power of attraction was not in the glass, because, if it were, why does not the glass always attract? When the glass is rubbed we say it is excited to electrical action or, in other words, is *charged with electricity.* When we draw the tube through the hand all the electrical effects disappear, and the inference is that the electricity has in some manner left the glass and disappeared. We, therefore, say it is *discharged.* What really happens when the tube is discharged in this way is that the hand becomes a conductor and carries the electricity off and it is practically lost—that is, lost as far as our experiments are concerned. To get new effects we must charge the glass over again by means of more friction.

We now need a more convenient method of finding out when anything is charged or discharged and you must construct a more complicated apparatus than any we have used before.

Procure a fruit-jar or wide-mouthed bottle and wipe

it clean and dry. Fit a wooden cork to it or place a thin slip of wood on the mouth. Get a short piece of stout copper wire, and bend about one inch of one end at a right angle. Pass it through the wood so that the bent end will hang in the bottle as in Picture No. IV. Roll



No. IV.

up the other end of the wire into a little knob or ball. Next cut a strip about an inch wide and three inches long from a leaf of the Dutch metal foil we used before, and hang this strip on the bent end of the wire in the jar as shown in Picture No. IV.

This apparatus is called an *electroscope,* and we shall

use it in a number of experiments to show the presence of electricity. Rub the tube and hold it over the little knob at the top of the wire, as shown in the picture. At once you will observe a curious effect in the little strip of foil suspended in the jar. The two parts or leaves fly apart. Touch the knob with the finger and they fall together again. We bring the charged tube near the copper wire (conductor) and the leaves fly apart. They are charged with electricity. We touch the wire and discharge it and they fall down again. Why they do this we will not stop to discover. It will be plainly shown by later experiments. Just now we will only notice that an electroscope is an apparatus for showing the presence of electricity, and by its aid we can go on to other experiments.

Make another pad as before, using, instead of silk, common flannel. Then get a stick of sealing-wax, the larger the better, and rub it with the flannel as we rubbed the glass tube with the silk. On holding the sealing wax over the bits of cotton and foil, we find the charged wax has precisely the same properties as the excited tube. We conclude from this that friction between other materials beside silk and glass can excite electrical action and give electrical effects.

You will find it a good plan to repeat all your experiments with the charged sealing wax, because while you

get the same results they are not so strong or marked as with the glass tube. From this we find that there may be a difference in the amount of attraction or other effects, though in kind they are alike. Try the wax also with the electroscope.

Having observed that electricity can be obtained from glass and sealing wax, we might go on and find that by friction electricity can be developed from many things. Warm a writing pad of Manilla paper before the fire, and rub the top sheet briskly with the hand, and it will be found that this sheet will be strongly attracted to the one beneath it. Many other things will display the property, and it is highly probable that all friction excites electricity in a greater or less degree. Electricity obtained by friction for this reason is called *frictional electricity.*

It is said that some one once brought to Faraday * a

* "Faraday," Michael. (1791–1867). An English chemist, and philosopher. He presents a remarkable instance of the success to be gained over such obstacles as poverty and lack of education, by patience and perseverance. At the age of thirteen he was apprenticed to a book-binder, but employed all of his spare moments in studying science, and in making experiments with implements of his own manufacture. He attended several evening lectures on chemistry, given by Sir Humphrey Davy, and ventured to send to the lecturer himself the notes he prepared on the lectures, which resulted in gaining for him

new experiment with a request that he would examine the results to be obtained. "Stop a moment," said Faraday, "before you begin, tell me what I am to observe." So we must learn what to observe. So far we have observed only the attraction caused by the rubbed glass or wax. Repeat the experiment with the glass tube, silk pad, and bits of foil. The bits of metal leap up to the glass, and then some of them fall back again, and again leap up, perhaps repeating the little flights up and down several times. Here is plainly something else to be observed. Why should the bits of foil behave in that manner? Are they attracted and then repelled? Is the attraction suspended for a few seconds, and then resumed? Clearly there is here a wholly different behavior, and we must infer there is another law governing it. We must find out this law by other experiments. We have already learned that electricity can be conducted through copper. Can it be conducted through other things? You must find

the position of assistant in the Royal Institution. Later, he accompanied Davy, as amanuensis, on a tour over the continent which lasted a year and a half. Shortly after this he began lecturing, and publishing articles on scientific subjects, and then there began that long series of important discoveries, accounts of which he gave to the public in volumes, having the subjects arranged according to their position in science.

an answer to this question before you can solve the others.

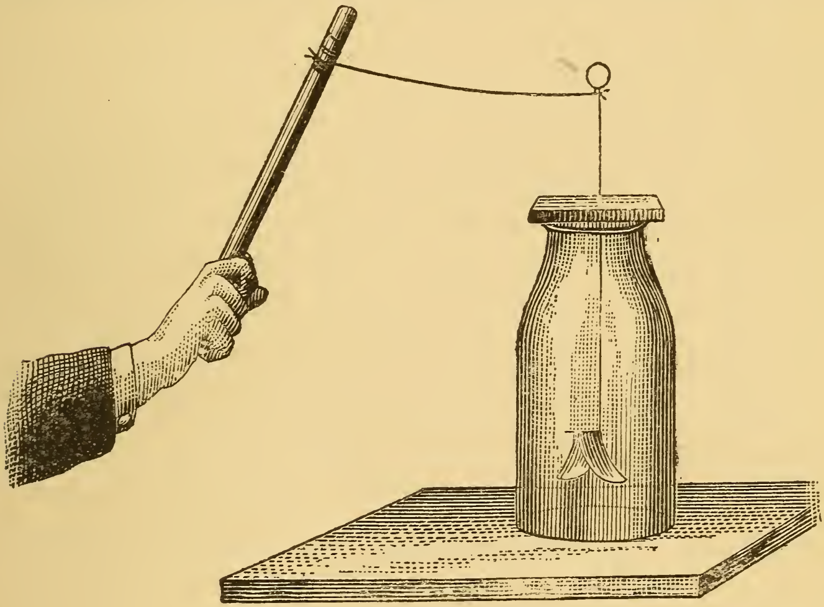
Get the glass, silk pad, the fine copper wire and the electroscope. Twist one end of the wire round the end of the glass tube as before, and twist the other end round the copper rod of the electroscope. Rub the tube with the silk, and instantly the two leaves of the electroscope start up, rising and falling slightly at every stroke of the rubber. Clearly the electricity developed by friction is conveyed through the copper wire.

We may make this experiment on a large scale by dropping a wire down the well of the stairs, and causing the leaves of the electroscope to be expanded on the first floor by rubbing the glass on the fourth floor.

Next procure about a yard of sewing silk. Tie one end of it to the end of the glass tube (without the wire), and the other end to the copper wire of the electroscope. You may rub the tube as hard as you please and there is no effect in the electroscope. To prevent any mistakes in the matter, use the sealing wax and flannel pad with the silk thread in the same way and the result is still the same. Your experiments prove that there is a difference between the copper wire and the sewing silk. As the little leaves are quiet while the glass or wax is rubbed, though connected by the thread, the inference is that the electricity cannot

travel through silk as it does through copper. We conclude then that some things do not conduct electricity, and we may call such things *non-conductors.*

Thus with the glass rod and the electroscope you can now make a series of tests with different materials and



No. V.

find out which are conductors and which are non-conductors. Try brass and iron wire, cotton twine, linen thread or any other material. Arrange each experiment as in Picture No. V.

Observe each trial carefully and make a list of all the things used, whether they are conductors or non-conductors. We shall return to this matter presently

and make further experiments with other apparatus. Meanwhile, fasten the silk thread (taking pains to see that it is perfectly dry) to the glass and the electroscope as in Picture No. V., and you can repeat Du Fay's * celebrated experiment in conduction. While the thread is dry no electricity is conveyed by the silk. Now carefully wet it through its whole length. Now the leaves of the electroscope fly apart at every stroke on the glass. Has the silk become a conductor? No. It is the water on the silk. Thus we see that water is a conductor, and that any non-conductor may become a conductor when wet with water. Repeat the experiment with other non-conductors, both dry and wet.

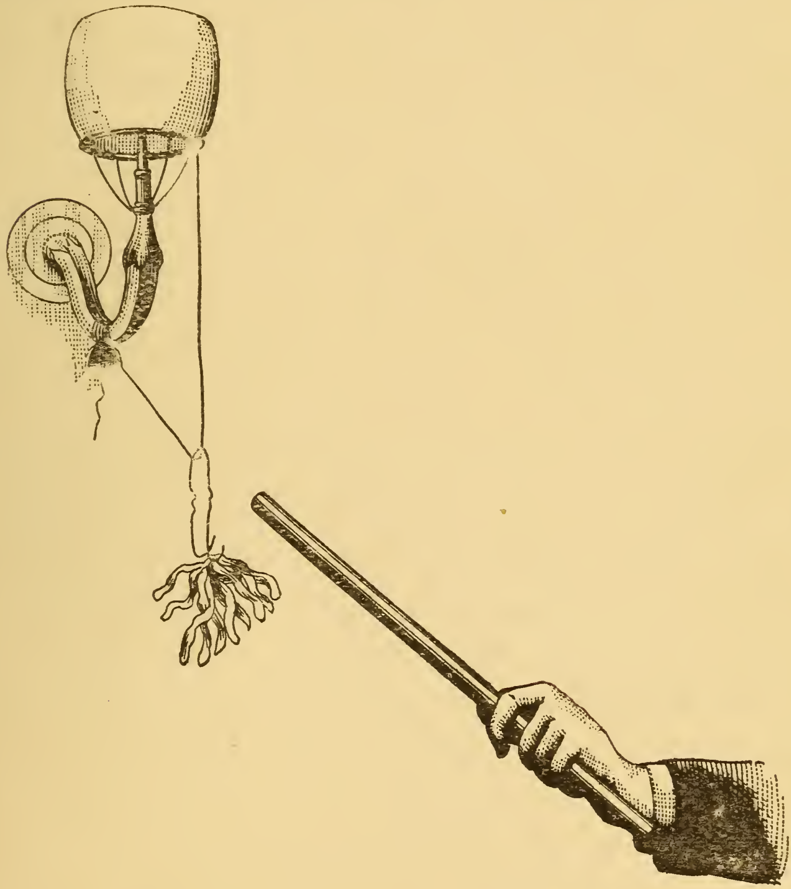
As it is not easy to try anything but threads and wires in this way, you may continue the experiment in another form.

Take a small sheet of tissue paper, and, folding it into a long and narrow strip, cut up one end into ribbons to form a tassel. Bend a hairpin in the middle to form a hook, push it through the tassel and suspend it by a silk thread from a gas lamp (or other projecting piece of furniture), as in Picture No. VI.

We are about to make an experiment that will teach

* "Du Fay," Charles François. (1698–1739). A French scholar who made many researches concerning the barometer, the magnet, electricity, etc.

us several things concerning the behavior of objects under the influence of electricity; but just now we will follow Faraday's example, and ask which of the various



No. VI.

phenomena we are to observe. We wish to examine a number of things to see which are conductors, and which non-conductors. We will observe this only at

present, and examine the other points a little later.

Rub the glass tube, and touch it to the ends of the hairpin. At once the paper tassel starts out in every direction. We may even take the tube away and the tassel will remain spread out. Touch it with the finger, and it collapses, falls together, and hangs down with every ribbon straight. Do this several times. We charge the tassel with electricity, and then remove or discharge it with the finger, plainly showing that the hand is a conductor. Try discharging with glass, wood, wax, metals, and anything else you can find, and make a list of the conductors and non-conductors.

Suspend the tassel by a copper wire, and repeat the experiment. No effects can be obtained. The electricity plainly leaks away through the wire. It seems the tassel must be suspended by silk—a non-conductor. Hang it up by the silk thread, and charge the tassel several times from the glass tube until the ribbons stand out in every direction. A little thought will show that, if the silk is a non-conductor, we are storing electricity in the tassel. If the air of the room is dry, the electricity cannot easily escape, and it remains in the tassel until it gradually escapes to the dust or invisible vapor in the air.

You have now reached a point in which you begin to see the value of your experiments. They have shown

you that electricity can be conveyed to a distance, as from the top to the bottom of a house, provided the wire does not touch anything. If you were to try it with a long wire placed horizontally, you must support the wire on something. If the supports are of metal, the electricity will pass through the supports and be lost. We may have already noticed in all this work that electricity is very fugitive or unstable. It escapes instantly at the first opportunity, seeking a way to the earth. To check this tendency to escape, you must support all conductors by non-conductors.

So we find at the very outset of our studies a great law that must be observed in the practical use of electricity. It can be conducted through the wire of a telegraph or telephone or fire-alarm, but the wire must be suspended from non-conductors. Wood when wet, as in a rain storm, will conduct electricity, and yet the telegraph wire is on a wooden pole. This is true, but observe the glass knobs to which the wire is fastened. Glass, as was shown by the experiments made with the paper tassel in arranging your lists of conductors and non-conductors, is a non-conductor, and we call these knobs on the poles *insulators* because they insulate or cut off the escape of the electricity precisely as water may cut off an island from the main land. We know that telegraph lines are laid under the seas. If water

is a conductor how can that be? Rubber, gutta-percha, silk, and other materials are wrapped round the wire to insulate the cable from the water.

This knowledge of conduction and insulation, conductors and non-conductors, gained by experiment is, therefore, of the utmost importance in all work connected with electricity. To make it still more clear, connect a long wire with the glass and the electroscope, and lay it from room to room along the floor. So arranged the experiment may fail. Let the wire rest everywhere on glass tumblers placed on the floor and it will work. Glass, as you may recall by referring to your lists of conductors and non-conductors, is a non-conductor, therefore the tumblers are insulators.

You can now return to the glass tube, the sealing wax, and the two pads and see what more can be done. You found that both glass and wax exhibit electrical attraction when charged by friction. Will electricity exhibit anything else? Get a very small, light feather and fasten it to the end of a yard of fine sewing silk. Tie the other end of the silk to a bracket, hanging lamp, or other projecting piece of furniture and we will try a new kind of experiment. Picture No. VI. shows how the feather and silk are prepared for the work.

Observe the condition of things. The feather is

suspended by a non-conductor. It is insulated and will keep for a few moments any electricity given to it. Bring the excited glass near it. It flies to meet the glass, touches it, and at once darts away from it. Try your best to touch it again and the feather flies round and round, trying its best to keep away from the glass. It is plain that it is no longer attracted, but is repelled. It now exhibits repulsion as well as attraction.

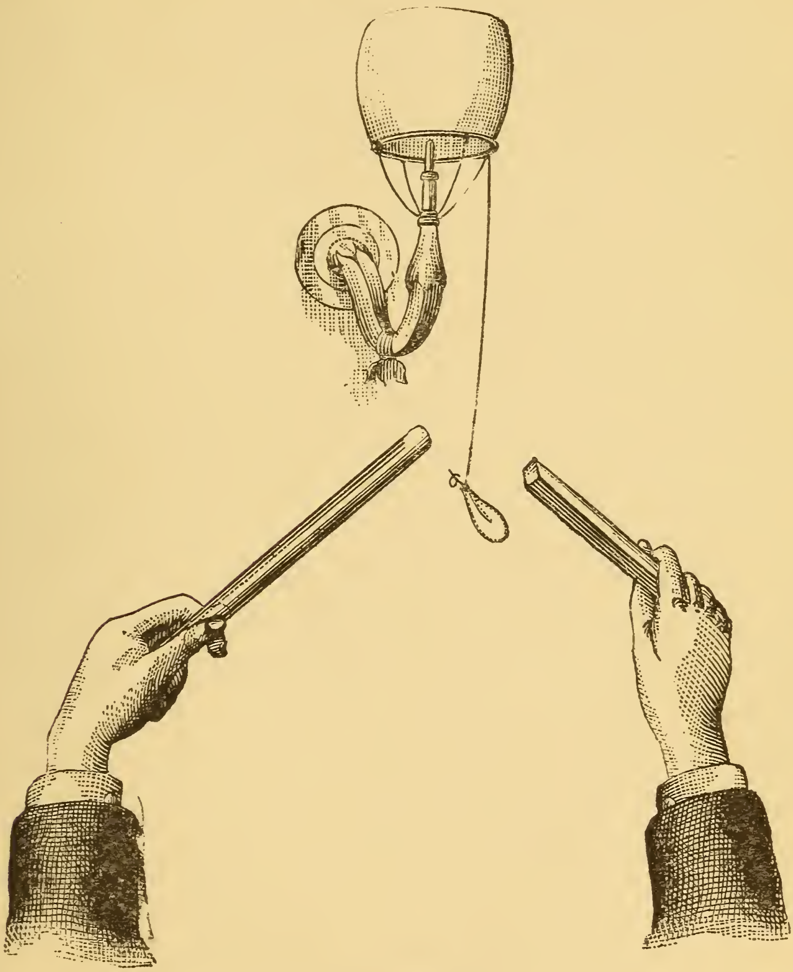
Discharge the feather by touching it and then recharge it, and at once hold one hand near the feather, and bring the rubbed glass near it and opposite the hand, or with the feather between the hand and the glass. At once a most extraordinary thing takes place. The feather leaps to the glass, and then flies to the hand, touches it, and then flies back again, only to repeat its little flight from glass to hand many times over. You remember the bits of foil behaved in the same way, leaping up and down between the glass and board several times. If you have forgotten how it behaved, repeat the experiment. Here is a singular performance and yet, by the use of a little imagination, we can find out why the feather behaves in this peculiar way.

Though we cannot see or hear or feel the electricity, we see its manifestations. The feather (when discharged) we may imagine as empty of electricity.

We develop electricity by friction on the glass, and bringing the glass near the feather, find it is attracted to it, touches it for an instant, and then flies away. In that instant's touch, we can imagine the feather loaded (or charged) with electricity. It has taken some electricity from the glass and yet there is some left in the tube. This you can prove by discharging the feather (touching it) and recharging it from the glass without rubbing the glass again. Both are charged and now instead of attraction there is repulsion. When we saw the feather dart backward and forward between the glass and hand it was attracted and charged, then repelled. It flew to the hand, discharged itself and was ready to be reattracted and recharged, when it was at once repelled. We can also repeat the experiment with the sealing wax and see the feather behave in precisely the same manner.

Now prepare for a much more complicated piece of work. Take the glass tube and let a friend take the sealing wax. Charge both by friction at the same time. When both are ready bring the glass near the feather. It is attracted, is charged, and then repelled. At once bring the excited wax near the feather and instead of being repelled it is attracted. Hold the glass on one side and the wax on the other, as in picture No. VII., and the feather will swing quickly from one

to the other. Try it again slowly, noting that while the feather, when charged by the glass, is repelled, it



No. VII.

is attracted by the wax. On touching the wax it is repelled and is attracted by the glass, and thus, alter-

nately attracted and repelled, it flies from one to the other in a curious dance of alternating love and hate.

Can it be there are two kinds of electricity? This is the fact. One of these is obtained by rubbing glass and it first received the name of *vitrious* (glass) electricity. For convenience we call it now *positive* electricity. The other kind was first called *resinous* electricity. We now call it *negative* electricity. When we charged the feather from the glass it was loaded with positive electricity or the same as on the glass. Then the feather was repelled. Are we not arriving at a law in this matter? *Positive electricity repels positive electricity.*

When the feather flew to the hand, or the bits of foil fell back on the table, they simply discharged their positive electricity and were ready to take more. How about the attraction to the sealing wax? Is its electricity of another kind? Yes. We are getting at the truth very fast. One more step and we are all right. The feather charged with *positive* electricity flew to the sealing wax because the electricity on it was *negative.*

Repeat the experiments carefully. Charge the feather with one electricity, and it is repelled. Charge it with the other, and it is attracted. Discharge it, and perform the experiment the other way, and the

same results are observed. Let one person charge the feather with positive or negative electricity, and then at once let another person, who has not seen the charging of the feather and who does not know which it is, try it with the glass. If it is attracted by the glass (positive), the electricity of the feather is negative ; if repelled, it is positive. So we have this great law: *Positive attracts negative, and repels positive. Negative attracts positive, and repels negative. Like repels; unlike attracts.*

Our bit of feather suspended by a silk thread, may seem a trifling affair, yet it teaches a great law in nature, a law which governs the lightning in the heavens, and, doubtless, affects that great star we call the sun, the worlds which swim round it, and the most distant star-dust lost in the interstellar spaces of the sky. On the knowledge of this law depends the success or failure of all our work in electricity, and until the law was recognized and understood, there could be no telegraphs, telephones, nor electric lights.

By these simple experiments, we ask questions of nature, and learn from common things some of the great principles which govern the Universe.

You charge the electroscope and its two drooping leaves fly apart, showing the presence of one kind of electricity. This explains its action when you used

it in other experiments. Then it was used merely to test the presence of electricity. It can also be used to tell whether any electricity whose presence it detects is positive or negative.

It is the same with the paper tassel. Every ribbon is filled with electricity, and each repels the other till they stand out in every direction. The bit of tin-foil which leaps up to the electrified glass in your very first experiment charges itself, and is repelled, but the instant it touches any conductor, it is discharged and is free to be attracted again. The feather on the silk thread cannot discharge itself, and is repelled till brought near electricity of the opposite kind.

So far you have demonstrated by your experiments that one of the manifestations of electricity is attraction, and that this attraction is between an electrified body and one not electrified, and between opposite electricities. We have learned that electricities of a like character repel each other; that there are conductors and non-conductors; and that, by means of a long conductor supported by non-conductors, electrical effects can be obtained at a great distance.

Otto Von Guericke,* of Magdeburg, was the first to

* "Otto Von Guericke." (1602–1686). A German philosopher, the inventor of the air-pump and a species of barometer. He was well known as an astronomer, and was the first to

observe the repulsion caused by electricity. Du Fay first made the experiment of attracting and then repelling a gold leaf floating in the air, and first made known this law of the effects of positive and negative electricity.

teach that the return of comets might be fixed upon. He advanced the theory of the two kinds of electricity. He also gave great labor and time to the study of botany.

CHAPTER III.

INDUCTION. THE EGG EXPERIMENTS. THE ELECTROPHORUS. THE LEYDEN-JAR.

All the experiments that you have performed will be helpful in trying others. If the new experiments you are now to take up seem complicated, go over carefully all that you have done before, and we shall have no trouble in understanding them.

Your experiments have already demonstrated that electricity may be excited by the friction of silk upon glass, or flannel upon sealing wax. You also observed that electricity is conducted by copper, and that it cannot be conducted by silk. Refer again to your list of conductors and non-conductors, as we shall now use both. The experiments demonstrated that the positive electricity from glass attracts the negative electricity of wax, and *vice versa*. Our experiments have shown us the law of attractions and repulsions—*like repels, unlike attracts.* Commit this law to memory for we must now use it as a key to new laws.

Get the small feather and fine silk thread we used

before, and suspend the feather by the thread from a gas lamp or other piece of furniture over the table and in easy reach. It will be found here that a pith ball, such as is included in the electrical outfit, is better than the feather. However, if you have none, use the feather. Have the board laid on the table, and warm the glass tube and the sealing wax and the two pads. Rub the glass briskly, and bring it near the feather. The feather flies to the glass, touches it, and is then repelled. The feather is now charged with positive electricity. It is said to be *polarized.* Rub the glass again without delay, and then, spreading the silk pad open, bring it near the feather. The feather flies to the pad. It is plainly attracted. If you fail, repeat the whole experiment, first *polarizing* the feather from the glass, till you see this attraction of the feather to the pad.

Never give up an experiment and say it will not work, because you fail to get the results expected. Distrust yourself before you distrust nature. We apply our law of attraction. If the positive feather is attracted, the pad must be negative. Use your imagination always in these experiments. Try to imagine the condition of things. The feather, you see, is positive. It was polarized by the glass. It flies to the

pad. There is only one conclusion. The pad must be negative.

Discharge the feather by holding it in the hand for a moment, and then repeat this whole experiment, using the wax and the flannel pad. This experiment confirms the other, and the flannel pad is proved to be positive. Clearly here is something new. Friction excites electricity, and the electricity found in the two things rubbed together is of opposite polarity. If one is positive, the other is negative. The whole subject is becoming more curious than ever. We are evidently close to a new aspect of the matter.

What is electricity? Is it anything that can be torn apart by friction? We certainly have friction, and, as a result, positive electricity and negative electricity. In one case the positive is on the glass, in the other, the negative is on the wax. The silk pad is negative, the flannel is positive. What is this singular thing that behaves in such a peculiar manner? This question has been a puzzle for a long time. We may ask what is water, and get a good answer quickly enough. No one is yet able to give as good an answer to the question before us. We can only say it is a result or manifestation of force. We use force and get friction and attractions and repulsions, but this does not tell us what electricity may be.

Benjamin Franklin tried to give a reasonable explanation of what we have just seen. He imagined that everything contained a curious, invisible fluid, and that when there was too much of this fluid present in anything, it displayed positive electricity; when it had too little, it exhibited negative electricity. This seemed a good notion, because by friction the regular supply of the fluid was upset, and too much or too little appeared.

Others have imagined that there might be two invisible fluids, and that when both were present, nothing happened, and no electricity could be found. By friction they could be pulled apart. When drawn apart, they attracted each other and pulled light bodies after them, as we have seen in our experiments. If two bodies held a fluid of the same kind, they repelled each other.

The question is not settled. Nobody knows whether there are such fluids. It is quite possible they do not exist at all. However, this notion that there are two fluids, whether true or not, will help us to understand our experiments. We call it a working notion, and we shall use it as an imaginary tool in our future experiments. Many people have thought that imagination was something to be regarded with mild disapproval as just a little vain and foolish. For such work as this, the Creator has given us in a vivid imagination one of

the best mental tools we can use, and the wise student takes pains to cultivate it. We may now go on to quite a different matter, and remembering this working notion try to use it as a tool in explaining new experiments.

Get a small stick of pine wood, a yard-stick, or a wooden ruler. Hang up the feather by the silk thread and place the table under the feather. Have the thread long enough to bring the feather within about five inches of the table. On the table place a tumbler or wineglass upside down, and on the tumbler lay the stick so that it rests even and quiet. Then push the glass and the stick toward the feather till the feather hangs opposite one end of the stick. If the stick is too low place books under the glass till the feather hangs directly opposite the end of the stick, but not touching it. Excite the glass tube and then hold it over the opposite end of the stick without touching it. At once the feather is attracted to the stick, swings toward it, touches it, and is then repelled. This looks very much as if the wooden stick on the insulated stand was acting as a conductor, conveying the positive electricity to the feather and charging it till it shows repulsion. Take the tube away from the stick and all the electrical effects disappear. This is certainly queer and quite unlike anything we have found before.

Repeat the experiment to make sure you observe all that happens. After the experiment is finished bring the tube near the feather and it is attracted. It is clearly not positive and obtained no electricity from the glass through the stick. Touch the stick with the excited glass and watch the effect. The stick is clearly charged and produces a marked effect on the feather. To understand this matter let us try other experiments.

Put an egg on its side on a small wineglass, get the electroscope and place these on the table near the suspended feather. Rub the glass tube, and hold it near one end of the egg. Observe that the egg is insulated, and whatever electricity is in it cannot escape. (Note. The egg, glass, and tube should be warm and dry.) Now, on the notion of the two fluids, what happened to the egg when the rubbed tube was brought near it? Nothing whatever is visible. We cannot see that anything happened and we must try to imagine what happened. We first imagine it holds electricity just as everything not in any way electrified by friction or other means holds it, in equal proportions of positive and negative. Remember our law, positive attracts negative. When the positive tube comes near the egg all the unlike or negative electricity in the egg is attracted to one end of the egg, as if to meet it. All the positive, on the other hand, tries to fly away from it.

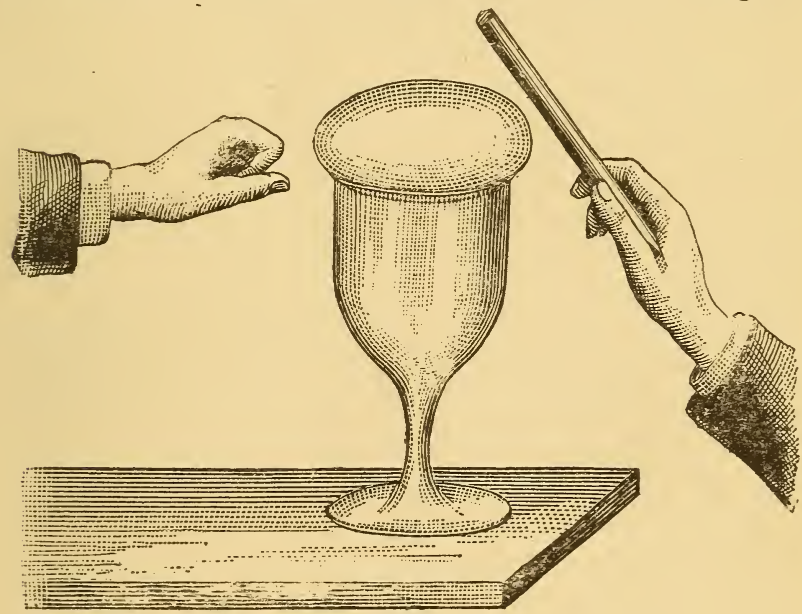
Neither can escape owing to the insulator (the wineglass), so all the negative gathers at one end as close to the positive tube as it can get, and the positive gathers at the opposite end as if trying to get as far away as possible. Take the tube away, and, lifting the wineglass, bring the egg near the feather and the electroscope. Not a trace of electricity can be found in the egg.

Repeat the experiment, and while the tube is still held close to the egg, bring the electroscope near the egg. Instantly it shows the egg is well charged with electricity. Take the tube away, and it is gone.

It is easy to imagine just what happened. The two electricities were pulled apart. When the tube was removed, they flowed together again. We imagined they collected at the ends of the egg when the tube was near. Can we prove this? Here you must notice that in this experiment, and in the experiment you performed just now with the insulated stick of wood, the excited tube is not allowed to really touch the stick or the egg. This effect, caused by bringing an electrified body (the glass) near an unelectrified body (the egg), is said to be produced by *induction.* When by friction the glass is made positive it has the power to attract the negative electricity in anything near it. This power is called the *power of induction,*

and all the effects we see are said to be caused by *electrical induction.*

Can we prove that there is this separation of the electricities in the egg by induction? Hold the excited tube near the egg. We can imagine the positive is now all at the opposite end and the negative all gath-



No. VIII.

ered close to the tube. Now, while the egg is thus subject to induction and the tube is still held near the egg, gently touch the opposite end of the egg with the knuckle and then draw the hand and the tube away. Raise the glass quickly and test the egg with the electroscope. The egg is highly electrical. To

understand just how the work is done look at Picture No. VIII.

One more step and we shall solve the puzzle. Discharge the egg, the electroscope, and the feather by touching them, and begin the experiment by bringing the rubbed tube near the feather till it is polarized or made positive, and is repelled. Now quickly rub the tube, and bring it near the egg, touch the opposite end as before, and then take away the tube. Lift the egg by the glass and bring it near the positive feather. The feather flies to meet it. Unlike attracts—the egg is negative.

Try to imagine all that happened. By induction the negative electricity in the egg was drawn to one end, and the positive was repelled to the other end. A touch of the finger allowed the positive to escape and leave the negative alone on the egg. When the tube was removed, the negative flowed all over the egg and covered it completely.

Discharge everything, repeat the whole experiment with the sealing wax, and prove the work.

Our experiment with the pine stick and feather was just like this experiment. The positive glass by induction drew all the negative electricity in the stick to one end, and the positive flew to the other end and at once attracted the feather. Now we can imagine

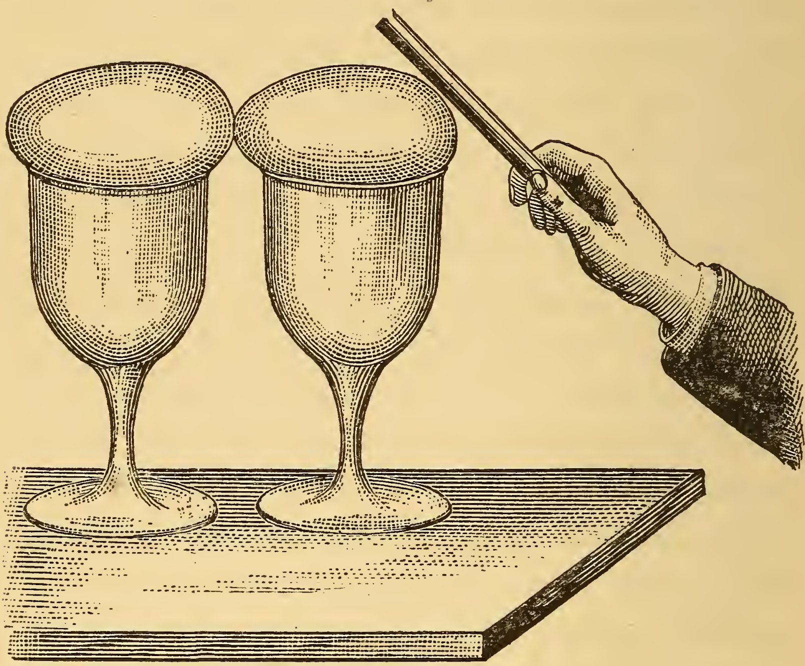
this as happening in everything near the positive glass, but in order to prove it we have to insulate the stick or the egg we use in the experiments, otherwise the negative might gather near the glass, but the positive would fly off somewhere and we could not find it. Only by insulation can we keep the electricity together long enough to enable us to see how it behaves.

Next, get one more egg and another wineglass and you may repeat the experiment in another way. Place the eggs, each on a glass as before, side by side, the two eggs just touching each other. Rub the glass and place it near one of the eggs. This is plainly shown in Picture No. IX.

While the tube is in that position, gently draw the second wineglass away to separate the eggs, and then remove the tube. Try to imagine what has happened. The two eggs touched each other and practically made one. The negative electricity of both gathered near the tube. The positive of both gathered at the distant end of the second egg. By drawing them apart we collected the positive in one egg, and the negative in the other.

See that all is discharged, and begin again, first polarizing the feather. Hold the egg pulled away near the feather, and observe what happens. Try the other egg with the feather. In this way prove

beyond dispute that all we imagined as taking place really did take place. Repeat the whole experiment with the sealing-wax, and prove which egg is positive and which is negative. Depend wholly on yourself. Settle everything by actual trials repeated at



No. IX.

least twice, and put down the results in your note-book for future reference.

Having obtained a clear idea of this singular matter of electrical induction, we can go on to other and even more interesting experiments. Get a circular

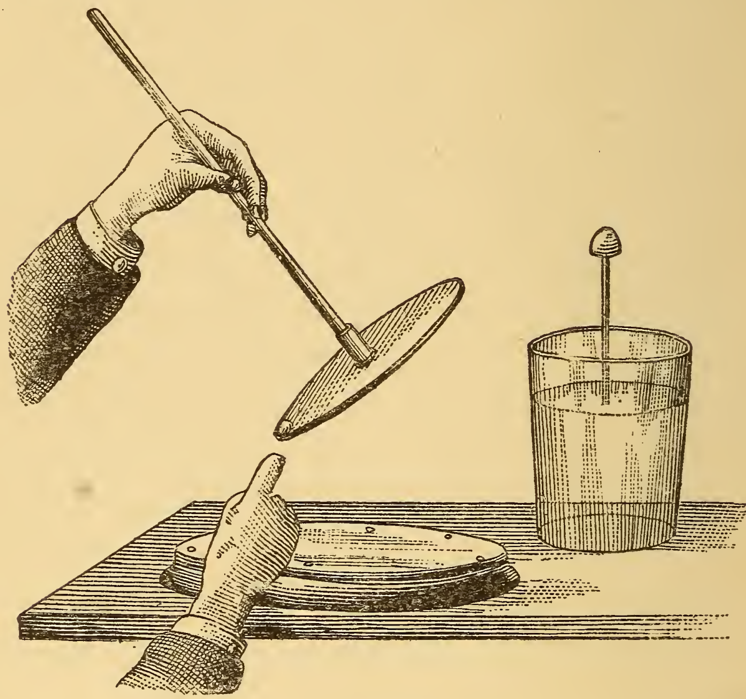
piece of thin vulcanite * about six inches in diameter, and fasten it to a round piece of dry wood with small tacks. Get also a circular piece of tin-plate about four inches in diameter. Heat the centre of this plate over a lamp, and when quite hot press the end of a stick of sealing wax against the plate. It will melt, stick fast, and, when cold, form an insulated handle. It will also be an improvement to fasten a round brass button or round bit of metal to the edge of the plate with a drop of sealing wax. Such an apparatus is called an *electrophorus,* and a similar apparatus, except that the handle is made of glass, is shown at the left in Picture No. X.

In some apparatus the handle of the tin-plate of the *electrophorus* is of glass and it can be used in place of the glass tube by unscrewing it from the plate. With such an apparatus you can perform nearly all the experiments already done, besides many more that will be quite as curious and instructive.

Warm the vulcanite plate of the *electrophorus* and then rub it hard with the flannel pad. Then lifting

* 1. "Vulcanite." Called also ebonite. India-rubber which, by a process called vulcanization, has been rendered hard like horn. This condition is brought about by combining the caoutchouc with sulphur by means of a very high temperature,—a process discovered by Prof. Goodyear.

the tin-plate by its handle lay it on the vulcanite. Lift it off and test it with the feather and the electroscope. No effect. Placing it on the rubbed vulcanite, which you may be sure was well charged by the friction, does not appear to affect it. It is clearly neutral or non-



No. X.

electrical. Put it back on the vulcanite, and while it rests there, touch the upper side quickly and gently with the finger. Now lift it and test it with the electroscope. It is highly electrical. Put it back on the vulcanite and touch it as before. It is again strongly

charged with electricity. In the *electrophorus* we have a practical electrical machine, for we can lay the plate on the vulcanite, touch it, and lift it off well charged with electricity for twenty or thirty times after once rubbing with the flannel pad.

Try to imagine what happens in this apparatus. It is plainly induction. On rubbing the vulcanite it is electrified and made negative. On laying the plate upon it the positive electricity of the plate is attracted to the under side, and is said to be *bound*. The negative is repelled and collects on the upper side, and is free to escape to the finger as soon as the plate is touched. For this reason it is called *free* electricity. Then on lifting the plate you find it contains only positive electricity.

Charge the feather with the tube as before, and repeat this experiment. Hold the plate to the feather. It is repelled, and the experiment proves that all we imagined took place really did take place. The plate can therefore be used in place of the glass tube in repeating all your previous experiments at a great saving of labor, because when once rubbed the vulcanite will act by induction on the plate many times over.

Take the *electrophorus* to a dark room, rub it briskly, put on the plate, touch it, then lift it by the handle,

and bring your knuckle near the button on the plate. There is a slight snap or cracking noise, and a tiny spark flies between the plate and hand, leaving a stinging sensation. Repeat this as many times as you wish, because it shows us wholly new phenomena. Electricity now manifests itself as light, as sound, and as a physical sensation. You can see, hear, and feel it.

Here is clearly something different from the attraction or the repulsion, the polarity, conduction, or non-conduction, or the induction we demonstrated by your experiments. The whole matter increases in interest, and we want to go on, to see, and to learn more. You now need something to enable us to keep electricity when we get it.

At the right in Picture No. X. is shown another apparatus easily made of cheap materials. Select a smooth glass tumbler, getting the best quality of cut glass. Make some flour paste and get a little common tin-foil. Then line the inside of the tumbler with the foil, covering the bottom and sides up to an inch of the top. Cover the outside also with foil to the same height, using the paste to keep the foil in place both outside and inside. Get a piece of stout copper wire, bend the lower part to form a little foot, and resting it on the foil inside the tumbler fasten it upright in that position with hot sealing wax. Then to the top fasten

with the wax a common brass button. All this is plainly shown in Picture No. X. See that it is well dried before a fire or in the sun, and then place it on the table with your electrophorus. Rub the vulcanite plate briskly, lay the tin-plate on it, touch the upper side gently, and then lifting it by the handle bring the little knob on the edge of the plate close to the button at the top of your new apparatus. There is a little snap and a tiny spark flies between them. Repeat this ten or twenty times in succession, placing the tin-plate on the vulcanite, touching it and holding it to the button to see the little spark.

Now take the tumbler in one hand, holding it by the tin-foil on the outside. Then touch the button on the wire with the other hand. The effect is surprising and peculiar. It may startle you, but while it stings for an instant it is perfectly harmless. It seems exactly as if we had loaded up the tumbler with a series of little sparks and then drew it all out in one big spark. Try it another way. Load it up again from the electrophorus and then let one person hold it in one hand while he gives the other hand to another person, and let this second person touch the top of the wire. Both feel the effect through their arms.

Let us try to imagine what happened in the tumbler during this experiment. The plate by induction held

free negative on the upper side as it rested on the vulcanite. You withdrew all the negative electricity when you touched it. On lifting the plate it held only positive electricity. On bringing it near the wire of your new apparatus the positive leaped across to the button and escaped down the wire to the tin-foil in the tumbler. Each time you repeated this there was a rush of positive electricity into the foil. You know *like repels—unlike attracts.* There was both positive and negative in the foil. The negative attracted the positive in the plate, and it being free and alone crossed over to meet its mate in the tin-foil. The negative in the foil also sprang across at the same instant into the plate. The two electricities crossed in their effort to equalize each other and be together. The whole process was repeated each time with this curious result. You continually removed the negative from the plate and it was restored by taking from the foil. The positive, on the other hand, could not get away from the foil because it was surrounded by the insulating glass of the tumbler. Thus it happened the inside foil was drained of its negative, and loaded up with more positive than it wanted.

During all this you can well imagine something must have been going on in the foil on the outside of the tumbler. Induction was here at work also. The two

foils were separated by the glass walls of the tumbler, yet induction acted across or through the glass. The inside foil, being strongly positive, by induction attracted all the negative of the outside foil and it gathered next the glass. It was very much as if it wanted to get through, but could not and so kept on that side as close to its companion as possible. The positive, on the other hand, was repelled and escaped in every direction into the table or any other conductor in reach. To help it get away it is a good plan to put the tumbler on a piece of wire that reaches to the floor or to the nearest gas or water pipe.

Now you have a curious state of affairs. Here are the two electricities close together, yet kept apart. Give them a chance and they will rush together with a loud snap and a bright spark. Let them use your hands and arms as a conductor and they flow together with a shock. They are of opposite polarity—*unlike attracts*—and you are pretty well aware of the vigor with which they rush together through your tingling fingers.

To prove all this place the tumbler on a small piece of window glass. If this is not convenient get four tumblers, warm them thoroughly and place them upside down on the table and lay a dry board or a book on them. This will make a little insulated table that

you can use in place of the sheet of glass. Then twist some fine copper wire round the top of the electroscope, and lay the other end on the insulated table and fasten it down by placing the tumbler on it. The outer tin-foil is now connected with the leaves of the electroscope, and the instant we begin to charge the inside foil from the electrophorus the electroscope indicates the presence of the electricity driven off from the outer foil.

The apparatus you have been using is called a *condenser* or *Leyden-jar*. When first used it was regarded with mingled horror and amazement. People thought it bewitched, and spoke of it with solemn awe as something just a little wicked and unnatural. It was first described by Kleist, of Cammin in Pomerania, in 1745. A year later, Cunæus, of Leyden, also discovered how to make one, and thus it got the name of *Leyden-jar*. Musschenbroek,* the savant (1692–1761), felt a shock from a jar and declared nothing would ever tempt him to try it again. Boze, another savant (1723–1788), declared he would willingly die of the shock, so great did he regard the doubtful honor of being killed

* "Musschenbroek" (1692–1761). A Dutch mathematician. He adopted the Newtonian system of philosophy, and helped introduce it into Holland. He held the chair of mathematics at Leyden for several years.

by such a truly wonderful and awful machine. Dr. Watson * and Dr. Bevis both improved it, and Franklin made it the subject of some researches and discoveries that were, at the time, thought to be very wonderful. Tyndall, of London (born 1820), invented some of the experiments you have tried with the Leyden-jar and the other apparatus, and greatly aided all students of this great science, who, like ourselves, wish to understand this complicated matter of induction.

* "Dr. Watson," Richard. (1737–1816). An English prelate. He was professor of chemistry in Cambridge.

CHAPTER IV.

THE CONTINUOUS INDUCTION MACHINE. THUNDER-STORM EXPERIMENTS. FRANKLIN'S BRAVERY IN THE PURSUIT OF KNOWLEDGE.

SELECT a dry evening when the air is clear and cold, and let us examine this matter of the behavior of electricity a little closer. If the weather is warm or wet, be sure and have the room in which you work dry. Get the electrophorus, the Leyden-jar, and other apparatus, wipe off all dust that may be on them, and warm them before a fire or over a lamp.

Let us begin with the electrophorus. See that the vulcanite and the flannel pad are warm and then rub briskly for a moment to electrify the vulcanite. Then put the tin-plate on it, touch it with the finger to draw off the free negative. Bring the knuckle near the button on the edge. The little spark appears. Try it on the Leyden-jar and the electroscope. Everything works well and you can go on to new work.

Get a shoe-buttoner, a hair-pin, and a large needle or one of the long sharp pins used by ladies for hat-pins.

Prepare the electrophorus and then take the shoe-buttoner in the hand, resting one finger on the steel part, if it has an ivory or other handle. Present the rounded end to the little button on the plate and a bright spark appears. Try the hair-pin, using the rounded end and holding it by the two points. Again a bright spark with some noise. Now turn the hair-pin round and present the points to the plate. Nothing happens. There is neither flash nor sound. Turn the lights down and repeat the experiments several times. Even in the dark only a very small spark can be seen. Try the needle or pin. No apparent results. It seems as if the electrophorus had completely failed. Try it with the knuckle or the shoe-buttoner and you will find it gives just as good sparks as ever. Fasten a fine copper wire to the button on the edge of the tin-plate, and connect the other end with the electroscope. Rub the vulcanite as before and put the plate on it, and then, without touching it, move it up and down an inch or two by the handle, and at every movement the leaves of the electroscope will rise and fall, plainly showing the presence of free electricity.

The experiments with the pins and the shoe-buttoner remind us of conduction. Let us consider this for a moment. The buttoner, hair-pin, and needle are all good conductors, and yet the electricity behaves in a

different way with each. Has it anything to do with the shape of the conductor? Observe the conditions of our experiments. We used rounded surfaces and points. With the rounded surface, like the knuckle or the round part of the hair-pin, there is a spark. With the points there was nothing to be seen or heard. We are reaching a new law in conduction: *Pointed conductors carry electricity through the air in silence.* With rounded surfaces the electricity flies across the little air space with light, heat, and sound. Points not only conduct electricity in silence, but act very quickly.

It is well to prove things by other experiments. Get a sheet of soft tissue paper, fold it up and cut it into strips so that when unfolded it will make a tassel. Fasten it to a hair-pin, and hang it up by a silk thread. (See Picture No. VI.) Charge it from the glass tube as in the former experiments or better from the electroscope till the tassel stands out in every direction. It has now electricity of one polarity, and as *like repels like*, every thread of the tassel stands out from every other. Next bring the closed hand or the knuckle under the tassel, but not near enough to touch it. If the hand moves the whole tassel follows it, but unless actually touched and fully discharged, the tassel is as stiff as ever. Now hold the long, sharp pin, or the needle in the hand under the tassel, point upward, and near

the centre. At once the tassel is discharged and the threads collapse. The sharp-pointed conductor instantly carries off the electricity where the rounded knuckle failed to remove any of it. Points are plainly silent conductors, and very good conductors. This you should note down and remember as part of the law of conduction.

Let us return a moment to our electrophorus. We rub the vulcanite with flannel and then lay the tin-plate upon it. You know from former experiments just what has happened. By friction the positive electricity is drawn off to the flannel, and the negative remains on the vulcanite. By induction, as illustrated by the experiments with the eggs, the positive electricity in the plate is attracted to the under side where it becomes *bound,* and the negative is driven to the upper side where it is free to escape the instant it is touched by any conductor. On lifting the plate the positive electricity flows all over it.

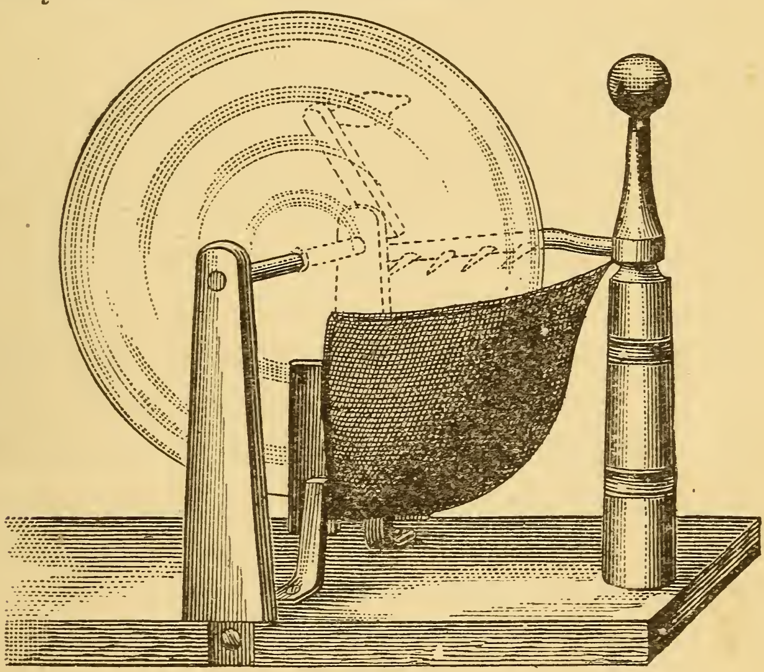
We cannot see anything of this. We use our imagination and see it in the mind. Experiments prove that our mind-picture is correct. On bringing the plate near a conductor the electricity seeks to equalize itself, and breaks through the air to meet the negative electricity in the knuckle or other conductor. There is a transfer both ways, positive to the finger and neg-

ative to the plate, and the plate is once more neutral or balanced, with both positive and negative in equal quantities. Put the plate on the vulcanite, and the whole process can be repeated many times. We make this little review of our work because it leads us to another kind of electrophorus.

Naturally the electrophorus is such a capital apparatus for your work and experiment, you might ask if there are no improvements to be made in it. It has been improved, and there are now several forms of continuous electrophorus, or machines giving a constant succession of electrical effects by induction.

Picture No. XI. represents a small cheap continuous electrophorus often used in schools. It consists of a round sheet of glass called the *plate*, supported on an arbor so that it may be turned by a hand-crank. Near the lower edge are two silk cushions or *rubbers* designed to press against the glass as it is turned around. At one end of the stand is a wooden upright, carrying an insulated standard of brass having a round knob at the top. From this part a brass arm extends along the side of the plate which is armed with a row of points that nearly touch the glass. This brass arm and standard are called the *prime conductor*. Between the prime conductor and the rubbers is suspended a silk bag enclosing a quarter

part of the plate. This makes an induction machine that is continuous. By turning the crank a continuous stream of sparks can be obtained from the prime conductor as long as the plate revolves. Such an apparatus is another form of electrophorus and is commonly called an *electrical machine.*



No. XI.

Recalling our past experiments in induction let us try to understand the theory of this machine. Here are silk rubbers pressing on glass, and, as we know from our experiments with the tube, separating the electricity, sending the positive to the glass and the

negative to the silk. That part of the plate thus excited moves on, as it turns, between the sides of the silk bag until it reaches the row of points on the prime conductor. Here induction takes place and the negative of the prime conductor streams from the points to the glass, leaving the free positive behind. The negative unites with the positive on the glass plate and balances it until, in turning, it meets the rubbers. Here by friction it is separated and the negative flies to the rubbers and escapes down the metal supports. As the plate moves on, the whole process is repeated continuously, and thus the machine becomes a continuous electrophorus.

Larger machines have two or more sets of rubbers and are sometimes very complicated, yet by the aid of your experiments with simple things you are able to readily understand the most complex machine you may meet in any future studies. Observe, however, that we here produce free positive electricity, while from the plate of the electrophorus we take free negative electricity. The result is precisely the same except in the polarity of the electricity. To ascertain the polarity of the machine use your glass rod and silk pad, and charge the little feather hanging by the silk thread till it is repelled, which proves its polarity is positive. (Consult your note-book about this.) Now turn the

crank of the electrical machine and holding the feather by its thread bring it near the prime conductor. It is still repelled—*like repels like.* This test must be made carefully and quickly to get the best results.

In using the machine, turn the crank with the right hand and place the left on the base of the machine resting against one of the metal pieces that support the rubbers. This will keep the machine steady and allow the negative electricity to escape through your hand and body to the ground. Unless some conductor is thus arranged, the machine works badly.

Turn the crank quickly ten times while some one holds the knob of your Leyden-jar to the prime conductor. A stream of small sparks will flow to the jar. Discharge the jar by holding it in one hand and touching the knob with the other hand. Another way is for one person to hold the jar and join hands with several others, the last person touching the knob. If the weather is favorable for work this will be probably as shocking a surprise as your friends will care to experience. A stronger charge in the jar might prove unpleasant, and you must make a *discharger.* Get a piece of copper wire, of medium size, about ten inches long. Roll up the ends into little knobs and bend it into a half circle. Set fire to the end of a short piece of sealing wax and press it against the middle of the copper wire. When

the wax is cold it will form an insulating handle for the wire. This is called a *discharger*.

Turn the handle of the machine briskly and hold the jar to the prime conductor. If working alone, a good plan is to connect the top of the jar with the prime conductor by a copper wire. The jar can then be filled quickly and silently. Now place one end of the discharger against the side of the jar (always hold it by the handle) and bring the other end near the knob. At once there is a vivid flash as the two electricities flow together. Repeat the experiment in the dark. Tiny sparks of fire will be seen streaming from the points of the prime conductor and running about inside of the jar when it is being filled by holding it near the machine. Besides the flash when the jar is discharged there will be also a brilliant ring of fire inside the jar.

It may be noted here that our Leyden-jar is a small one. A larger jar would hold more and give larger and louder sparks. Instead of one large jar you might use several at once. Four or more jars like the one you have made can be placed on the insulated table or on a sheet of glass and the wires be all connected by a piece of copper wire. Another piece of wire must be tied round the outside foil of all of them. This would form a *battery* of jars and give very large and powerful effects. They could be arranged in another way, in-

vented by Franklin. Get two jars and place them on the insulated table, then connect with a wire the bottom (outside) of one with the top of the wire of the next. You can easily imagine what would happen now. By induction the free electricity of one jar drawn off by induction from the outside foil would escape through the wire into the next jar, there to again produce induction. Franklin arranged several jars in this way and called the apparatus a *cascade battery.*

With your electrical machine, Leyden-jar, and discharger you can now perform a number of electrical experiments. Cut some Dutch metal into bits a quarter of an inch long, and paste these in a row across the bottom of a flat tumbler. Put the pieces on the glass about a sixteenth of an inch apart. When dry put the finger on one end of the line of pieces of foil and bring the other end near the prime conductor of the machine while the crank is turned. In the dark a pretty stream of fire will be seen playing along the spaces between the pieces of Dutch metal.

Warm four glass tumblers and place them upside down on the floor and lay a board over them. Let one person stand on the board and rest his hand on the prime conductor, while another turns the crank rapidly. Curious effects will be seen in the way the hair stands erect on the head. Any one touching the face or

hands of the person on the insulated stand can draw a spark. With a little practice the person on the stand can also light a gas jet with a touch of the finger. Another experiment is to charge the jar and then, holding a piece of letter paper near the knob, use the discharger to send a spark through the paper. It will make a minute hole in the paper.

So far in our work you have demonstrated by your experiments that electricity attracts and repels, that it has polarity, that like polarity repels, unlike attracts. You showed that it can be conducted and that there are conductors and non-conductors, and that there is a difference between rounded and pointed surfaces in their power of conduction. You have also demonstrated the behavior of electricity under conduction, which is really a mode of action under the influence of attraction and repulsion.

It seems almost strange that this great science can be reduced to so few, simple, and easily remembered laws. This is one of the grand features of nature. The greatest results are produced by the most simple laws. These laws when understood explain the most marvellous exhibitions of power in nature. It is by these laws the four phenomena you observed when we began our studies are explained. The crackling sounds in the girl's hair as she combed it out, the sparks in the cat's fur,

the sticky behavior of the lint on the dress all came from frictional electricity. Even the lightning follows the laws of induction.

We noticed that by induction electricity may be *bound* or held. This has led to a special name for the electricity we have been considering, and it is called *static* electricity. It is also called *frictional* electricity and, as it can always be found in the air, it is sometimes called *atmospheric* electricity. There is free positive or negative electricity in the air at all times. It comes from the friction of the air on the earth or, as we shall see by other experiments, is excited by other means. Its grandest display is in the lightning.

A cloud moves over the earth in the air, and from friction or some other cause becomes positive. By induction the negative electricity in the earth rises to meet it and follows trees, houses, or other tall objects to get as near the positive cloud as possible. If the mutual attraction is strong enough a flash leaps through the air as the electricities come together.

A cloud may be positive or negative, and approaching another cloud, act by induction, drawing the opposite electricity to the side nearest to it and holding it there, leaving the free electricity to escape

in a flash to still another cloud or to the earth. Perhaps the two opposite electricities unite with a flash and leave the free electricity to flash with a return or second stroke. Either of these effects of induction may take place whenever the clouds and the earth resemble a huge Leyden-jar, as in a thunder-storm.

A cloud appears and passes over a forest. Every point on every leaf conveys away the electricity, like the points in an electrical machine, in silence. The cloud moves on, perhaps still highly polarized, and passes over a house. Induction takes place; the house is polarized, and the opposite electricity not finding points enough from which it can stream off in silence, breaks from the house to the cloud with a terrible crash, and the house is destroyed or set on fire. A man seeking shelter under a tree is killed. His body is a better conductor than the tree, and the electricity moved by induction goes from the cloud to the ground, or from the ground to the cloud through the tree and then through the man, and the shock is so great his life is destroyed. It makes no difference what the polarity or direction of the flash as the effects are the same. The cloud may act by induction; opposite electricities may unite or free electricity escape from the cloud to the earth or vice versa.

It was an American who, seeing the relation between

the conducting power of points and rounded surfaces, first applied it to atmospheric electricity. He tried in other ways the same experiments you have tried, and in writing about them he said: "If these things are so, may not the knowledge of this power of points be of use to mankind in preserving houses, churches, ships, etc., from the stroke of lightning, by directing us to fix, on the highest parts of those edifices, upright rods of iron made sharp as a needle, and gilt, to prevent rusting, and from the foot of those rods a wire down the outside of the building into the ground, or down one of the shrouds of a ship and down her side till it reaches the water? Would not these pointed rods probably draw the electrical fire silently out of a cloud before it came nigh enough to strike, and thereby secure us from that most sudden and terrible mischief?"

This man had the courage to put this to the test of a great and daring experiment. We can hardly understand such magnificent courage in the pursuit of knowledge. Standing with his son in an open field, near what is now the corner of Race and Eighth streets, Philadelphia, he put up in a thunder-storm a silk kite. At the top was a sharp pointed wire. The kite string when wet by the rain was a conductor, and at the lower end was a piece of silk ribbon as an insula-

tor. On the string hung a key, and from this key sprang to the man's hand the first spark that proved that the lightning was static electricity. We can well understand his courage when we learn that a year later another experimenter, Richmann, of St. Petersburg, repeating this experiment, with a tall pole in place of a kite, was instantly killed. To-day Franklin's experiment is to be seen in every lightning rod on spire or ship.

Static electricity is used to light gas lamps in halls and churches by employing a small electrophorus or induction machine to give a spark. It is used also for moving light bodies in certain machinery, to fire great guns on ships, and to explode powder or dynamite in blasting. To understand the uses of electricity in other ways, we must go on to other experiments and continue our studies in other branches of this great science.

CHAPTER V.

MAGNETISM. A SHORT CUT ACROSS ANOTHER FIELD OF SCIENCE.

Long years ago people, like ourselves, anxious to learn something of nature by asking her questions, found a certain iron-stone or iron-ore that had the singular property of attracting pieces of iron when brought near the stone. For some unknown reason such iron-stones received the name of *loadstones*. As some of this ore was found near the ancient city of Magnesia in Asia a better name was given to it. Pieces of the ore were called *magnets* and this curious property of attraction was called *magnetism.* Still later the ore was called *magnetic iron,* all these terms being naturally suggested by the name of the old city.

For centuries men seemed to be content to know this little and nothing more. Only in quite modern times did any one seek to learn more by experimenting with these loadstones or magnets. It is true, that many hundreds of years ago in China a use was found

for these magnets, but why these stones possessed this curious property no one seems to have cared to find out. The use made of magnets in China we shall learn presently. Just now we may notice that magnets have been known for a very long time, and yet it is only within a very few years that their greatest value was discovered. To-day there are thousands on thousands in daily use all around us and without them business would almost come to a stand-still.

It was early found that if a piece of iron be rubbed on one of these loadstones it too would have the power of magnetic attraction and be a magnet. The bits of stone are not easy to use in our experiments, and we shall find it better to get a steel magnet. You can buy one for a small sum at the optician's or the maker of scientific apparatus. It was found that when common soft iron is rubbed on a loadstone to cause it to become a magnet, it in time loses its magnetic property and will no longer exhibit any trace of magnetism. Steel, on the other hand, will keep it for a long time. So it happened they were classified as *natural magnets* or loadstones, as *temporary magnets,* and *permanent magnets.* Your small steel magnet bent into the shape of the letter U is a permanent magnet, and from its shape it is commonly called

a *horseshoe magnet.* Magnets made of straight pieces of steel are called *bar magnets.*

There is one other kind of magnet. This we shall examine a little later. In all this you may think we are travelling very far from studies in electricity. It seems so, yet we are really on the right path and shall return to electricity in the end. Just now we shorten the road by "cutting cross lots" through another field of science.

Get the magnet, some small iron tacks or nails and some iron filings. Get also a sheet of stiff writing-paper. No special pains need to be taken about the temperature or dryness of the room and the experiments can be performed anywhere and at any time. The first thing you observe about the magnet is the piece of iron that comes with it, and that is usually attached to the two ends of the magnet. With a little effort it can be pulled off. There is no gum or paste on the magnet, and this clinging of the bit of iron to the magnet is not due to anything of that kind. The piece of iron is called an *armature.* Now take the armature in one hand and the magnet in the other, and slowly bring the armature opposite to the ends of the magnet. As it comes nearer there is a curious pull or attraction growing rapidly stronger and stronger till the armature jumps to the magnet and sticks fast.

Here is plainly a permanent attraction, and you notice that it is not caused by friction as in your electrical experiments.

Take the armature off and try it on all parts of the magnet and you quickly prove that this magnetic attraction or the attraction of magnetism is only at the ends of the magnet, which are called the *poles*. Take off the armature and try the magnet on the nails. The attraction is so strong that the nails can be lifted by the magnet though they may touch it only by the points or sharp corners. Pull the nails off and then try one on another. No effect. It is plain that the nail did not take any magnetism from the magnet or, if it did, lost it very quickly. Try the armature on the magnet. It is as strongly attracted as ever. It is plain enough that the magnet did not lose any magnetism while the nails were clinging to it, nor did it give its magnetism to the nails when they were removed.

Next make two piles of books on the table and lay the sheet of paper across from one to another to form a little bridge. Stretch the paper tight and put more books on the edges to keep it in place. Then scatter some of the iron filings on the paper, and then hold the magnet under and touching the paper. Move it about in that position and the iron filings will follow

the unseen magnet in the most curious manner possible.

A novel use was recently made of this experiment. The figures of a clock were painted on a tambourine so that it looked like a clock dial. The tambourine was then used for the cover of a neat box. On the upper side was an imitation beetle or spider, made of iron, that travelled round the clock face and thus indicated the time of day. There was no machinery visible and it seemed marvellous that the beetle thus moved round and round the clock dial. It was all simple enough when you were told that under the tambourine was a real clock with a magnet for an hour hand, and, as the magnet moved round and round, the armature-beetle crept after it.

In like manner you can make the iron filings assume the most fantastic figures by moving the magnet about under the paper. You easily see what this experiment shows. The magnetic attraction passes through the paper. It is not a non-conductor. You can also try silk, linen, or other materials, and prove that none of them are non-conductors. The paper is really a conductor, that is, the magnetism passes through it, but it cannot conduct the magnetism to a distance as we saw copper conduct electricity. If a thick board is used in place of the paper it may appear to be a non-conductor.

Repeat the experiment with the armature and magnet alone and you recall the fact that the power of attraction extends only a little way from the magnet. The thick board does not cut off the magnetism from the iron filings, but simply keeps them beyond the reach of the attraction. The little space about the poles of the magnet where the magnetic attraction is felt is called the *magnetic field.* The board is merely thicker than the field is wide.

Try the paper bridge and the iron filings again. Hold the magnet under the paper and then give the paper a little snap or jar with the finger to make the filings dance about, and they will form curious groups around the spot over the ends of the magnet. This grouping of the filings shows how the magnetic field extends invisibly about the poles of the magnet. There is in this experiment another matter we might consider, but will leave it for the present while we look at something else.

Next use the paper bridge to test other things to see if they are attracted by the magnet. Try copper or brass filings, feathers, sand of any kind, or other light objects. Try larger things directly with the magnet, and make a list of the things that are attracted. You will find it a very small list. Try metals and alloys of metals. If the alloys contain iron they will be attracted

though there may also be other metals mixed with it. A very pretty test experiment is to try the magnet on pins. If they are attracted they are made of iron wire that has been whitened or silvered. If they are not attracted they are of brass. A curious use for magnets has been found in our great flour mills and elevators. Groups or "gangs" of magnets are placed in the spouts that are used to convey wheat or corn to the stones or bins in the mills and elevators. The corn and wheat sweep past untouched. A rusty nail, or bit of iron wire from a wire-binder in the wheat field, a speck of iron from the harvester passing through the spout is caugnt by the magnets and thus kept out of the mill-stones where it might do great harm to the stones or be turned to dust and mixed with our breakfast rolls.

Get a large straight steel knitting-needle and holding it by one hand draw it twenty times across the poles of the magnet. Touch the iron filings with the needle and you see that it too is a magnet. Try the armature on the magnet to see if it has lost any of its magnetism. It is as strong as ever and you see at once another curious thing. A permanent magnet may give magnetism to a piece of steel without apparent loss to itself, and the steel will become a new permanent magnet. We have now a straight or *bar magnet.* Roll the

bar magnet in the iron filings and they will gather at each end in curious bunches, and showing exactly how the invisible magnetic field covers the two poles. Wipe off the iron filings and let us try something else.

Get a thread, and tying it round the middle of the magnetized needle, hang it up so that it will swing freely in any direction. When it is resting, quietly supported by the thread in the middle, bring the horseshoe magnet (without the armature) near it, and the needle being attracted will swing round towards it. Now carry out the experiment very carefully in this way: bring one arm of the magnet near one end of the needle, and the needle will be either attracted or repelled. It will be one or the other very plainly. Look at the magnet, and on one arm you will find a mark. This is to indicate the *positive* or *north pole* (or end) of the magnet. The other end is called the *south* or *negative pole.* Recalling your electrical experiments we remember that positive attracts negative and repels positive, and that negative electricity behaves in relatively the same way. We reduced this to a law by saying, *unlike attracts, like repels.* Our suspended magnet obeys the same law. It has a positive and a negative pole, and by experiment we can discover which end is positive, and which is negative. If the positive pole of the magnet repels one end of the needle, that end must be

positive and the other end negative, and the opposite holds true if tried with the other pole of the magnet. This gives us the law of magnets, *like poles repel, unlike poles attract.*

Let us return to the magnet. Put on the armature and hold it near a tack. It clings to the armature, and with a little practice you can cause the suspended tack to pick up another, and that another, till you have a string of half a dozen hanging by the magnet. Here is a most singular thing, because you see that the last or lowest tack is far away from the small magnetic field of the magnet itself. Try to attract the tack when resting alone at the same distance it is now and no effect will be seen. It is too far away to be attracted and yet there it hangs. This comes from the fact that each tack in the line is for the time a little temporary magnet. The first one becomes a magnet by *induction,* and that by induction controls the next, and so on. Thus there is magnetic induction as well as electrical induction. Refer again to your note-book to understand this clearly. This induction explains also the groupings of the iron filings on the paper and on the ends of the bar magnet. Each little particle of iron became by induction a magnet.

In some school cabinets can be found a small magnetized needle that can be balanced on a little standard.

This apparatus is called a *dipping needle*, and, if you had one, experiment would prove that it has, like the suspended needle, a north and a south pole.

Observe now that while such a needle is at rest it at all times points in one particular direction. Why it should behave in this way we shall discover by later experiments, and we must be content now to know that this direction is north or toward the magnetic pole of the earth. You perhaps recognize this needle as the basis of the mariner's compass, the oldest and perhaps the most important scientific tool ever made, and the only practical application made of magnetism until modern times.

By its use ships can be guided across the sea and without it navigation would be almost impossible. It is plain we have opened the door to a most fascinating and delightful field of experiment. You could go on for a long time studying these laws of magnetism, but already we are in sight of our old road. The cross-cut path brings us back to electricity far in advance of the place where we left it. Keep your notes on magnetism. You will need them for reference in future work.

CHAPTER VI.

CURRENT ELECTRICITY. THE ELECTRO-MAGNET. ELECTRO-MAGNETISM.

GET a copper two-cent piece and at the tinman's buy a bit of sheet-roofing zinc, about two inches square. Get also a few yards of fine *insulated* copper wire. This is wire bound with fine threads of silk or other material. You see what is meant by *insulated wire.* It is a wire conductor protected everywhere by a non-conductor so that when electricity is sent through the copper, it will not escape to your hands and thus be lost. Punch a hole in the zinc, and then scraping some of the insulation from the end of the wire, tie the bare wire to the zinc through the hole. Cut it off about two feet long and remove an inch of the insulation from the other end. Prepare another piece of wire in the same way and twist one of the bare ends round the copper coin. Then, holding the two metals by the wires, drop them into a cup of strong vinegar, taking pains to see that the zinc and copper are well covered and that they do not touch each other. The wires

must hang over the edge of the cup and not touch each other.

Nothing appears to happen. The two metals seem to rest quietly in the vinegar without producing any effect whatever. There is really a chemical change going on in the cup. The acid is attacking the two metals, the zinc slowly and the copper very slowly. In time part of the zinc will be quite eaten away. Touch the bare copper of one of the wires to your tongue. There is nothing. Try the other—no effect. Now put the ends of both wires on your tongue at the same time. There is a faint, acrid, biting taste on the tongue as long as the two wires rest there. This effect is certainly quite different from anything we have observed before. Very little can be done with this apparatus except to give this peculiar taste in the mouth. By using better apparatus you will discover that we are once more on the old path we travelled before we turned aside to look at magnetism.

Our work now requires more complicated apparatus, and you should get, if possible, what is called a small galvanic battery. The apparatus consists of a glass bottle with a brass stopper, and suspended from the stopper are two pieces of carbon and a piece of zinc. The zinc is fastened to a rod so that it can be raised and lowered at will, a set screw being used to hold the rod

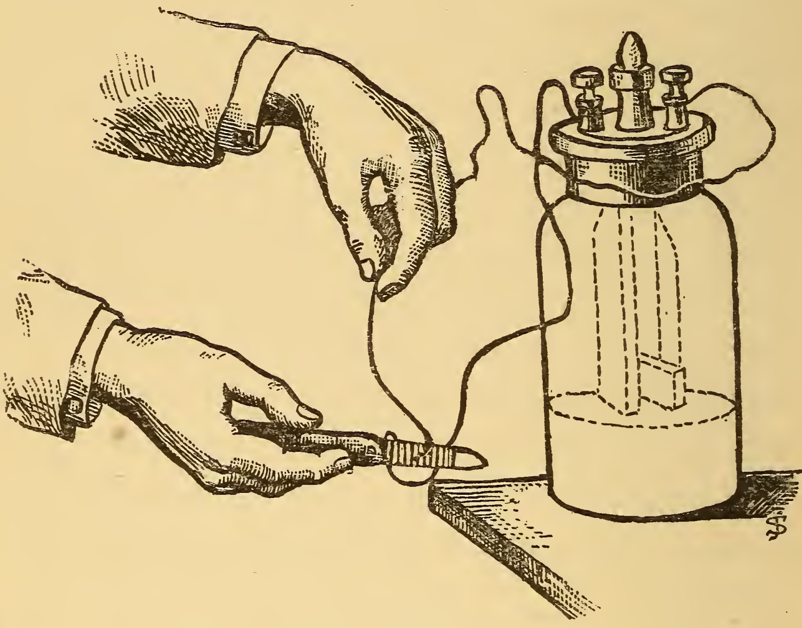
in place In the bottle is placed a mixture of sulphuric acid and a solution of bi-chromate of potash.

Such an apparatus is called a *battery,* and is made ready for our work by loosening the set-screw and letting the zinc drop into the liquid. On the top of the bottle are two pieces of brass called *binding posts.* Use the insulated copper wires again, and fasten the bared end of each piece to the binding posts by slipping the ends into the little holes and fastening them in place by the screws.

Next, open the blade of your pocket knife that has the little file for the finger nail, and twist one end of the bared wire round the blade. Hold the other wire by the insulated part and touch the end to the file. As they meet there will be a tiny spark. Try the experiment in a dark room and drag the end of the wire over the file and a little shower of sparks will fly from the file. Picture No. XII. shows how the experiment is done.

It is plain that these sparks are electrical. They resemble the sparks from the electrical machine, except that they are more numerous and seem to come from the file and the wire in a continuous stream or current. You have again obtained electricity and without friction or any apparent motion and without any exertion

on your part. This battery is clearly very different from the glass tube, the electrophorus and the electrical machine. You have seen that motion and friction or mechanical action can be used to produce electricity. Here we have chemical action. We can understand by imagination what takes place in the battery. Acids



No. XII.

corrode and dissolve metals. Now it has been learned from a long series of experiments that acids dissolve metals at different rates. For instance, vinegar is an acid and it attacks zinc slowly. It also attacks copper, but very slowly indeed. In your battery a stronger acid is used and zinc and carbon are exposed

to it and are attacked or dissolved (eaten up), but the zinc faster than the carbon.

Here are two chemical actions going on side by side at different speeds, and whenever this happens the electrical quiet is disturbed. Just as with friction the two electricities are pulled apart, so in the battery there is a pulling apart and there is a positive electricity and a negative electricity each trying to get away from each other, and each trying to find its opposite that they may rush together and restore the balance upset by the action of the acid on the metals.

In the electrical machine you obtained a spark, and then another and another, and so on. It was a series of different electrical effects with little pauses between the sparks. In the Leyden-jar you saw a series of these sparks all joined together in one bright flash. When the zinc and copper were placed in the cup of vinegar electrical action began at once and then continued. You remember the peculiar taste on the tongue was continuous as long as the wires touched the tongue.

In your last experiment it seemed as if the sparks were broken and came one after the other. It was really a continuous stream or current, the sparks appearing at the instant when the wire and the knife blade touched or were pulled apart. Thus electricity from a battery or from a chemical source is called *current electricity*, to

distinguish it from the *static electricity* you obtained by friction. While the two metals rest in the acid there is electrical action, but it is invisible and not of much use. By fastening a conductor to each of the metals we make a path for the two electricities to travel up from the metals and acid. When you bring the bared ends of the two wires together, positive and negative rush across through the air in a tiny spark, giving both heat and light. Then, so long as the wires touch, the positive and negative flow silently and invisibly in a current or stream through the two conductors. Pull the wires apart and we see the flash as they try to leap across at the instant the wires part. Every time the ends of the wires are brought together or pulled apart we catch a glimpse of the current that is always flowing through the wires when they are joined together. Lift the zinc out of the acid and all action stops. There is now only the carbon in the acid bath and no electrical effects appear.

Put the zinc back and you have two materials dissolving at different speeds, and electricity flows like an invisible rivulet between them along the joined wires. Even when the wires are not joined there will be a current if the ends of the two wires touch another conductor (like a gas lamp), for the current will flow away into the earth. Each polarity will seek its opposite by

our old law—*unlike attracts*—and the electrical action will go on growing fainter and fainter till the acid is too weak to affect the metals, or till the zinc is so injured that it will no longer dissolve, or till it completely disappears. For this reason you will find it a good plan always to lift the zinc out of the acid when you are not using the battery, and thus prevent the battery from wearing out.

You might go on and perform many interesting experiments showing the character and behavior of this current electricity, and its effects upon different materials. Our aim is to see how electricity can be used in work, in business and social life, and we must omit many things that are both curious and interesting and take up experiments that may help us to understand the uses of electricity. It is sufficient now to observe that current electricity is both positive and negative, and that it behaves according to the same laws of attraction and repulsion and manifests all the effects of induction that you observed in your previous experiments.

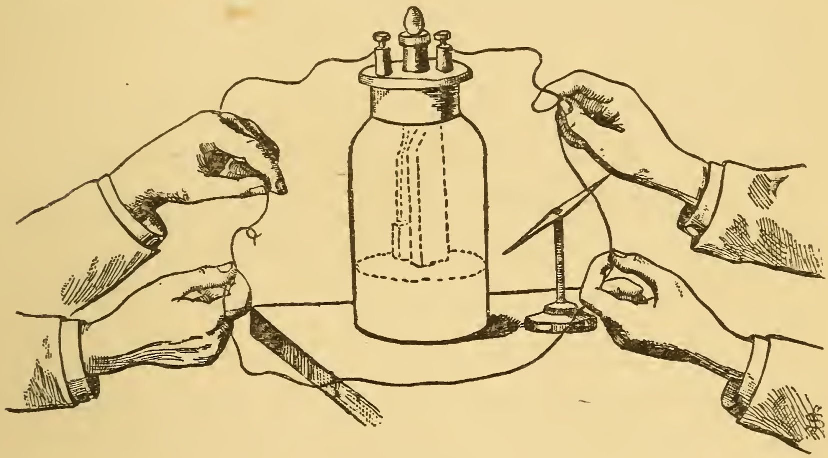
Take the wires off the knife blade and prepare for another experiment. Now the two wires are separated and the current ceases to act. Next, fasten the two wires together by twisting the ends firmly. Now the conductors touch and the current is silently flowing through both and we have what is called a *closed circuit.*

When the wires are separated, even for a very small space, the circuit is said to be open ; it is an *open circuit.* When the circuit is closed the current flows till the zinc is lifted out of the acid. When the zinc is again lowered into the acid the current flows again. So there are two ways of opening the circuit : first, by breaking the wire, and, second, by raising the zinc and stopping the chemical action in the battery. When the battery is in order and the circuit closed, the current will flow for many hours or till the zinc is destroyed or the acid becomes so weak it will not work.

Fasten the two wires together to close the circuit and get the dipping needle. Lift the zinc in the battery, and then hold a portion of the wire straight and parallel to the needle and just above it. While the wire is in this position have the zinc lowered into the acid, and at once the needle behaves in a most singular manner. It forgets to turn to the north and swings round and at a right angle with the wire. Unfasten the wires and bend the ends into hooks and then, while one person holds the wire over the needle, let another close and open the circuit by means of the hooks. Each time the circuit is closed the needle will stand across the wire. It is plain that the current in the wire has some mysterious influence over the needle, and you can perform a number of interesting experi-

ments by holding the wire under as well as over the magnet and in different parts of the circuit. Picture No. XIII. shows the way in which this experiment should be performed.

This experiment, simple as it is, shows us one of the



No. XIII.

great laws in electrical science. Study the experiment carefully and see what it means. The dipping needle is a magnet and, being free to move, it turns to the north or towards the magnetic pole. When the insulated conductor is held over it, the current in the conductor has the power of turning the needle till it stands directly across the conductor. It cannot be the wire, because only when the circuit is closed and the current flows does it behave in this singular manner. As this always happens, we say it is a law of freely suspended

magnets that they stand always at right angles or across the path of any current of electricity passing near them. As the conductor is insulated this behavior of the needle is caused by induction, for you will observe the needle does not touch the wire and is not brought into contact with the conductor and cannot be electrified.

Two curious facts suggest themselves by this experiment. When the dipping needle is free to move as it will, it always points to the north. If it turns across the path of an electrical current, may there not be at all times currents of electricity flowing from west to east round the earth. We cannot think of any other reason why the needle points north, and, though we cannot see or feel these earth currents travelling round our planet, every mariner's compass seems to plainly show that such currents do always travel round the world.

Another and more useful fact is indicated by your experiment. If the needle turns in this way across the path of an electrical current, may it not be used to indicate the presence of a current. This is plainly what happened, for only when the circuit was closed did the needle move, and by watching the needle you could tell precisely when the current flowed even

though you had no other means of knowing it was in the wire. From this you see it was not difficult to make a machine for detecting the presence of electricity. This little experiment is the basis of a remarkable apparatus called a *galvanometer*, and used to detect and measure a current of electricity in any conductor. The galvanometer has a swinging needle that marks the presence of the most feeble and delicate currents, and proves that they are moving when they are so feeble that we have no other means of detecting their presence.

This swinging magnetic needle was at one time used in telegraphing, and is still used in long cables under the sea, its swing to and fro as the circuit is opened and closed indicating the letters of the words in a cable message. We might spend a long time in studying the galvanometer and learn much that is both curious and interesting. It is best, however, to turn to another experiment showing a still closer connection between electricity and magnetism.

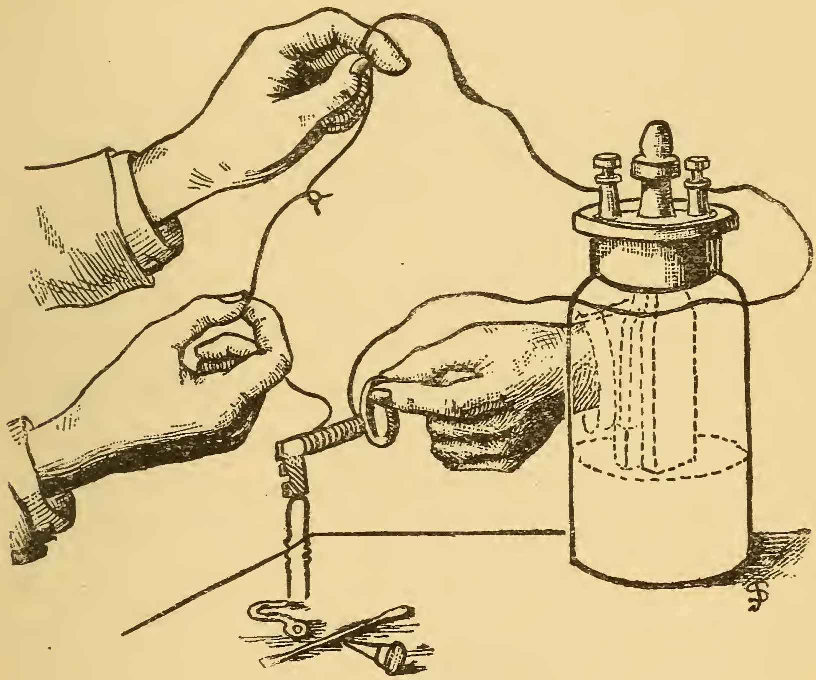
Get a common iron key and wind the insulated part of one of the wires round and round the key in a spiral from the handle to the wards. Leave the end of the wire loose to form a hook as before and to be used in closing and opening the circuit. Leave the circuit

open and get a tack, a small hair-pin, or other small iron object. Touch it with the key, holding it by the handle. There is no effect. Now close the circuit and try the key again and we discover perhaps the most remarkable thing in this science. The key is a magnet. Open the circuit and the key ceases to be a magnet. Close it again and it once more attracts small pieces of iron, and they cling to it precisely as to our horseshoe magnet. Observe the conditions of our experiment. We have a piece of soft iron (the key), and we have twisted about it an insulated wire conveying a current of electricity. The silk prevents the electricity from escaping to the key or from leaping across from spiral to spiral along the key, and it must travel round and round it. The result is extraordinary. The soft iron key is a magnet as long as the current flows, and ceases to be a magnet the instant the circuit is broken. Picture No. XIV. shows just how the whole affair works.

We have here a current of electricity flowing round an iron bar and insulated from it. The effect is therefore caused by induction. It is an induced magnet and as it is given this property by electricity it is called an *electro-magnet*. We have used a small battery, a little insulated wire and an iron key, and yet with these sim-

ple things we have made the most remarkable and perhaps the most useful tool ever invented.

The electro-magnet is now as common as the plough, the sewing-machine, the loom, or printing-press, and like these great tools it has entered into our daily life



No. XIV.

and business and marks one of the great steps of human progress. As electricity can in this simple manner be used to make an electro-magnet, the magnetism displayed by the soft iron while it is affected by the current has naturally received the name of *electro-*

magnetism. This makes the last and most valuable of the magnets, and we have now the natural magnets or loadstones, the temporary magnets, as when a piece of soft iron is touched to a magnet, the permanent magnets, and the electro-magnets. We have the permanent magnetism of the horseshoe magnets and the electro-magnetism of the electro-magnets. The dipping needle may be an electro-magnet; the currents of electricity travelling round the earth from west to east create electro-magnetism in it. Our earth itself is a great magnet.

It is not difficult to go a step farther in imagination and trace electricity and magnetism to the sun and even to the most distant star. There are, the astronomers tell us, electrical disturbances in the sun, and when such electrical storms rage in the sun 90,000,000 miles away, every little electro-magnet in our telegraph offices is affected by some strange magnetic sympathy across the interstellar spaces. May not all action, mechanical or chemical, whether it be the turning of a little crank or the swift swing of a giant star create electricity and turn whole worlds into electro-magnets.

The acid in a cup stirs a current in two bits of metal. May not the sea and land or the materials of a sun be vast batteries producing currents that reach across the world and the universe. There is no longer anything special or peculiar to our little world. Electricity and

magnetism are intimately related, they may be even different manifestations of the same thing, and they are universal. The laws we have learned from your little experiments operate here and in the most distant star.

In 1790 Galvani made his first famous experiments in electricity and gave his name to this particular form of electricity we have examined and it was at first called *Galvanism.* In 1792 Volta, of Pavia, carried Galvani's experiments still further and his name also became associated with the science, as electricity from a battery is sometimes called *Voltaic electricity.* Oersted and Ampère carried out researches in electro-magnetism and made its laws known, and Faraday contributed many great and important experiments in this science. Had we time we could well afford to spend a year's study in this one branch of electricity. As it is, all we can do is to remember what we have learned in order to apply our knowledge to the understanding of the practical uses of electricity in work and business.

CHAPTER VII.

THE LAST STEPS. ELECTRIC SIGNALS. THE TELEGRAPH. THE TELEPHONE. THE ELECTRIC LIGHT. THE UNITY OF NATURE.

WE have now observed some of the more simple manifestations of electricity. You have demonstrated by experiment the few grand laws that govern these manifestations, and you have shown how electricity may produce magnetism. One more step upward and we shall reach high ground, where we can look back along our path and look abroad over the whole vast field of magnetic and electric invention. When we have made this last step in electricity we shall be able to understand something of the general principles governing all the marvellous machines and appliances that have produced such wonderful changes within the past few years. Our first steps may seem only a few easy paces on a long and intricate road, yet it is one of the wonders of nature that, when we come earnestly to study her laws, we find these laws are few in number and as complete in operation as they are simple in design.

In the school cabinets can be found a small apparatus resembling a barrel or cylinder. It consists of two coils of insulated copper wire, one formed of a long piece of fine wire and the other made of a shorter piece of much larger wire. The shorter coil is placed inside the longer coil and each is carefully insulated from the other. The inside or short coil is called the *primary coil*. The larger outside coil is called the *secondary coil*. While one is much larger than the other they are both wound in spirals, and being one inside the other the two wires are parallel through all their windings. The primary coil can be connected, by means of short wires, with the battery, and a current of electricity will then travel through the primary coil inside the secondary coil. While the current thus flows through the primary coil nothing appears to happen. Open the circuit (by means of hooks as in your experiment with the current and dipping needle), and at the instant the circuit is opened there will be a throb of electricity in the secondary coil. It is like a beat or pulse and lasts only for an instant. On closing the circuit the same momentary flash of electricity will stir in the secondary coil. If you can open and close the circuit very quickly, there will be in the secondary coil a series of these electrical beats following each other just as fast as you *make and break* the circuit.

By using the discharger you made for the Leyden-jar you can obtain brilliant sparks from the two binding posts on top of the apparatus. This secondary current, produced at every make and break in the primary current, is said to be *induced.* The apparatus works by induction and is called an *induction coil.* The secondary current is also called an *alternating* current because its direction or polarity (positive or negative) is changed alternately at every opening and closing of the primary circuit.

In some induction coils the primary is enclosed in the secondary and cannot be taken out. If it could be taken out and put back at will, you might perform another experiment. Suppose you could do this and that the primary coil was connected with the battery (closed circuit) and the current passed through it. Then on putting it inside the secondary coil there would be the same short pulse or beat of electricity in the secondary coil. There would be the same effect on taking it out. The experiment would show that the mere movement of a coil carrying a current will induce a secondary current when it is put in or taken out of the secondary coil, and without making or breaking the primary circuit. There are thus two ways of producing the secondary current, the first, however, being the most simple and easy.

You have already seen by your experiments with the electro-magnet that electricity will produce magnetism. By the aid of an induction coil it has been learned that magnetism may produce electricity. If a bar magnet be pushed into a secondary coil (the primary coil being taken out), there will be a pulse of electricity in the secondary coil at the instant it is put inside the coil. The same thing will take place when it is taken out, the direction of the secondary current changing each time the magnet is put in or taken out. Another curious fact has been learned. If a piece of soft iron or a bundle of iron wires is put in a secondary coil and then a permanent magnet is brought near the soft iron (in the coil) it will become a magnet by induction. (This you have already proved.) Then, if the magnet is merely moved forward or backward before the iron a current of electricity will appear in the secondary coil. We could go one step farther and put the permanent magnet inside the coil, and then holding the armature in the hand move it backward and forward in the field of the magnet and produce a secondary current of electricity in the coil.

The same thing would happen if an electro-magnet were placed inside the secondary coil. In the induction coils used in schools there is, inside the primary coil, a bundle of soft iron wires, and at one end of the

bundle is an armature supported by a spring. If you connect the primary coil with your battery, the bundle of wires becomes an electro-magnet. The armature will be then attracted towards the wires and touch them. At once the spring would tend to pull it away, and in doing so would, by means of a *shunt* or short loop wire, open the circuit. Attraction would cease, but the recoil or backward movement of the spring would throw it into place again, close the circuit and bring it in the magnetic field only to be attracted again. In this manner the armature would rapidly beat backward and forward alternately making and breaking the circuit. This rapid opening and closing of the circuit would produce a rapid stream of alternating positive and negative beats that would form a powerful electric-current. Connect the two binding posts on top of the coil and this secondary current can be used for experiments. Try the two wires and file used in your experiment with the electrical battery and a brilliant shower of sparks will be obtained. Use care with this apparatus as the secondary current may give unpleasant shocks if allowed to pass through the hands.

Electricity obtained by induction from any form of magnet is called *magneto-electricity,* and any apparatus using such electricity is called a *magneto-electric appa-*

ratus. This method of obtaining electricity is now the most important and the cheapest, and as a result is the most common wherever large and powerful currents are used.

Let us take one more step. Suppose we have two magnets, one a large permanent magnet and the other a small electro-magnet. By using these together it would be possible to obtain currents of electricity without the use of a battery. Not from the magnets alone. In nature there is no such thing as a gift. There must be something paid for something received. To these magnets we must add motion or movement of some kind. From what we have learned it is easy to imagine that if the poles of the electro-magnet are brought near the poles of the permanent magnet there will be a throb of electricity in the wire wound round the electro-magnet. This flash of electricity would appear in the wires just as the electro-magnet entered the magnetic field. In like manner there would be another pulse or beat in the wire, when the electro-magnet is taken out of the field. There is motion or movement in each case and we learn that motion will produce electricity. It would not be difficult to mount the electro-magnet on a shaft, and by means of a crank to cause its poles to pass in turn through the magnetic field. Each time its poles en-

tered and left the field there would be an induced current in the wires of the electro-magnet. If the crank was then turned very fast, the beats or throbs of electricity would follow quickly in a stream. By means of springs resting on the revolving electro-magnet we could conduct the current to a wire and thus lead it anywhere we wished.

It is not surprising that having learned this much men soon took one more step, the last and most important of all. In place of the permanent magnet as a source of magnetism an electro-magnet was used, and to charge it a part of the current from the moving magnet was taken through its coil, and thus magnetism was obtained in large quantities and used to induce still larger quantities of electricity. This brings us to a point that seems to form a new starting-place in this science. A water-wheel or steam-engine could be harnessed to such a magneto-electric machine and its force or power be used to obtain electricity. Such a machine is called a *dynamo-electric machine* or simply a *dynamo*. It means literally—*force-electric-machine* or *power machine*. We cannot use a dynamo in your experiments as they are costly and demand great force to move them. We can, however, see presently what can be done with the great streams of electricity that flow from a dynamo.

These last steps taken in imagination bring us, as it were, to the top of a hill where we can rest and look about. Before us are all the strange new tools and apparatus used in electricity. At first glance they seem mysterious and complicated, yet all are founded on the few simple laws shown to us by your experiments. The road stretches on and upward along many a steep and difficult path 'til it is lost in the mist that seems to hide the unknown and undiscovered. While we may not all of us go any farther along this road we may be sure that those who do so will find the same laws governing all the manifestations of electricity in both nature and art. You should go on. It is to be hoped you will take with other guides more steps in the study of nature, and advance to more skill in experimenting, more knowledge, and a wider outlook over this great field of science.

However, even these few steps have brought us to a point where we can understand the general principles that underlie all electrical work. Suppose we look about a little and try to see how the laws demonstrated by your experiments are used in the arts, in manufactures and business. We call at a friend's house and look for the big brass knocker or the handle of the door bell. They have disappeared and instead of lifting the heavy knocker or pulling the handle we gently touch

a button with one finger. The merest touch, and yet in a moment the maid opens the door. She must have been informed in some way that we were at the door. We ask how it was done. It is perfectly proper to do so. Always ask questions. Never hesitate to inquire about any matter you do not understand. Better be inquisitive than ignorant.

Our friend shows us the whole thing. Simple enough—a little battery, some wires, an electro-magnet, and a bell. The whole affair is arranged in this way. In some closet is a battery. From this battery extend along the walls or behind the plastering two wires. They reach to the front door, then to the kitchen and then to the battery and form an insulated circuit for the battery current. At the door the wire is cut and forms an open circuit precisely as in your experiments. The two ends are close together and when we touched the little button at the door we merely pushed them together and closed the circuit. In the kitchen the wires are joined to the coil of a little electro-magnet. For an armature this electro-magnet has a bar of soft iron supported on a spring, and carrying a rod having a little hammer that hangs near a brass bell. When the circuit is open the electro-magnet is quiet and inactive and the spring keeps the armature away from its poles. When we closed the

circuit at the door the magnet attracted the armature and its hammer struck the bell, and the sound notified the maid that we wished to enter the house. When we released the push-button the circuit opened, the magnet was demagnetized and the armature was pulled back into its old place ready to strike again the next time the circuit is closed.

In this simple apparatus, which you might rig up for yourself at home for a dollar or two, we have the general principle on which all call bells, alarms, indicators, fire and burglar alarms of every kind are made. There are, of course, a great many modifications, many different methods of using these principles, and in some appliances of this kind there are many complicated and apparently perplexing details. Yet, under all changes, through all the many curious details, there are these two ideas, a battery and circuit and an electro-magnet. There are also many kinds of bells used in such electric alarms. There are tiny chattering bells that whir and tinkle in fretful repetitions. There are big bells that strike loud strokes, one, two, three, or more times, each stroke serving for a signal. For instance one stroke may mean the maid is wanted, two strokes a fire is wanted upstairs, or three strokes tell that breakfast is ready. The bells may be hung high in church steeples and suddenly in

the quiet night, when all the town is asleep, every bell may clang out curious numbered strokes that tell of a fire in some district. The booming sounds come over the house tops in succession from far and near bells, and make a musical clamor on the air. Yet, really, every bell was struck at the same instant by one man, who with a touch of the finger clangs twenty church bells, miles apart over the city.

We go to a hotel and see in the office a large dial having many numbers, each covered by a little shield or mask. We hear a bell ring and see one of the shields fall and display a number. Here is both a signal by sound, and also a visible signal or number to indicate in which room of the house the circuit was closed. We call at a factory and see on the ceiling little discs of metal placed at intervals between two wires that stretch along the ceiling. We ask what that means and the proprietor tells us that, if a blaze should start up from the machinery of the factory and threaten to burn the building down, one of those discs on the ceiling would melt and the fire bells would ring at the nearest engine house. The ordinary heat of the room would not affect the discs. A lighted match held close to one of them would melt it, close or open the circuit through the wires, and sound the fire bells.

We visit a farm and are shown an incubator or machine for hatching eggs by artificial heat. Now in such an apparatus it is very important that the temperature in which the eggs are kept should be the same at all times. There is a thermometer inside to show the temperature. Certainly it is a most curious thermometer for, if the mercury rises too high the dampers of the fire are turned or the wicks are turned down in the oil stove. Soon the mercury falls again and then by some mysterious apparatus the wicks are turned up and the stove gives out its heat again. It's not so mysterious as it appears. We may be sure that somewhere near is a battery or conductor forming a circuit and an electro-magnet. We call on some friend who lives in a house having the very latest improvements and find in every room a thermometer that closes the dampers in the furnace the moment the rooms become too warm.

Perhaps we go down Broadway in New York at noon and see hundreds of people looking at a black ball on a pole at the top of a large building on the corner of Dey Street. Suddenly the ball drops to the foot of the pole, and all the people look at their watches to see if they agree with the government clock at Washington. We enter a business office near by and find a curious machine covered by a glass bell. The machine

moves by fits and starts, and from a slit in the side of the case supporting the glass cover slides out a ribbon of paper having curious marks and letters printed on it. Dignified old gentlemen read the paper ribbon with becoming gravity, as if in search of valuable information. It seems very odd to see an elderly gentleman watch such a fretful little machine. When we learn that a battery, a circuit, and some electro-magnets are telling him the news of the market we begin to see how your little experiments explain complicated inventions of the greatest value to business men all over the world.

We go to a bank near by and find singular doors and windows and curious door-mats. The bank president informs us that, if at night when the bank is closed, any one should open a door or window, or even tread on that innocent mat, an electric circuit would be opened, an armature clinging to its electro-magnet would be released and fall, striking a bell and showing a number in the nearest police station and the officers would quickly be on hand to see what was the matter. The robber might know all this and cut the wires. This would be a pretty mistake, for cutting the wire would be opening the circuit and the bell would clang and the police appear.

An engineer of the express is leaning out his cab win-

dow looking ahead for lights while his engine rushes along through the darkness. His life, the lives of all the people in the sleepers behind him depend on these lights along the way. He sees a white light ahead. All right, and he lets the throttle open a little wider. As the engine sweeps past, the white light turns to red. There is a curious click on the track hardly noticed in the roar of the train. Half a mile ahead a bell is ringing loudly at a lonely crossing in the woods. A belated milkman hears the bell and waits till the approaching train flies past and the crossing is safe. As the train approaches a town the sleepy passengers in the waiting-room hear a chattering bell and pick up their bags and wraps, glad to know the train is coming. The train moves on and suddenly the engineer sees a red light ahead. He shuts off steam, puts on the air brake, and with a jar the train stops. A train man goes ahead to the red light. Nothing to be seen. He goes on still further and finds a train stopped on the road. Hot box. No thoroughfare for the train behind till things are cooled off and the train in front goes on. The moment it is a mile away the red light changes to white. The line is clear. Go ahead.

In all these instances and in many more equally curious and interesting you can trace your little experiment with the battery, the wires, and the iron key.

In each of these widely different applications of electricity there is a battery, an electric circuit through some conductor, an electro-magnet whose armature moves forward or backward as the circuit is opened or closed. The forward wheel of the truck of the locomotive pushes down a lever that projects above the head of the rail. The circuit is closed, the red lamp displayed, and the bells ring at the crossing and the station. The red lamp remains visible behind the train to warn any following train till the engine in front is a mile away, and then the wheel pushes down another lever, opens the circuit again and the armature of the electro-magnet by the lamp lets the red target fall and the lamp burns white again. It is the same in every messenger-call, burglar, or fire alarm, annunciator, time-ball, electric clock, electric heat regulator, electric recorder, "ticker," railroad target, or other warning bell or call of any kind. Through every complication of machinery, under all the complex details there lies the law that at the opening of an electric circuit there is magnetism in a piece of soft iron round which the wire is wound. Your iron key and wire may seem a trifling bit of apparatus and yet they show the use of one of the most important tools ever invented.

Recalling your experiment you may wonder how such a small and weak attraction as the electro-magnet

shows can produce such great results. Surely the tiny swing of the armature could not ring a church bell. This is a good question, but a few moments' thought will explain it. Take the time-ball. It is easy for a man to raise the ball on the pole and then to fasten the rope or other means of support to a spring, carefully balanced so that the slightest touch will release it. The pendulum of the clock at Washington swings to and fro, and just at the right instant it strikes a little pin, opens the circuit in that city and the magnet at New York releases the spring and the ball falls. It is the same with the church bell. A heavy weight has been wound up and made fast to a carefully balanced spring or lever that will move at even the gentle touch of the electro-magnet. It is not the magnet or its armature that rings the bell, but the weight that in pulling swings the great hammer till the bell roars with sonorous clang. This may not be the precise way in which it is done, yet it explains the principle by which it is done. For instance, you remember that the burglar alarm operated on a circuit that was always closed, and that the opening of the circuit rings the alarm bell. A moment's thought shows how that is done. The circuit is closed and the electro-magnet holds the armature tight. When the circuit is broken the armature is released and by its

weight or the pull of a spring it strikes the bell. It may operate in still another way. The release of the armature may set in motion clock-work already wound up and ready to start the instant the armature is free.

The point is just this :—the opening or closing of an electric circuit causes the armature of a magnet to move. Its tiny spring gives us the power to *control work at a distance.* It makes no matter how complicated the mechanism, in every case the electro-magnet is the one tool that accomplishes all these wonders.

The touch of a hand, the tread of a wheel, the pressure of a footstep, the rise of the mercury in a thermometer, the swing of a pendulum, any slight movement may open or close a circuit. In like manner the tiny play of an armature miles away may start or stop the most powerful machinery, be it controlled by a weight, or water wheel, or steam-engine. So it comes that your experiment hints at great and splendid inventions whereby the gentle touch of a magnet may strike a church bell, move a railroad target, tend a furnace fire, set an engine in motion or steer a ship.

We sometimes wonder at the telegraph and forget that this great science of signaling is its twin brother. All these uses of a battery and circuit and an electro-magnet began with the birth of the telegraph about fifty years ago. Let us once more recall your experiments

and see if they may not be a key to unlock the mystery of the telegraph.

It is not difficult to imagine that, if a pen be fastened to an armature, its little swing to and fro, as the circuit is opened or closed, might be used to scratch marks on paper and these marks might stand for letters and words. On such a simple idea as this rests the great science of telegraphy. The first telegraph used by Morse between Baltimore and Washington was no more than this: a battery, two wires, a key for opening and closing the circuit, an electro-magnet, and a little apparatus whereby the armature would make little dents on a ribbon of paper. Out of how small a matter have grown such marvellous things. It is no wonder that the first electro-magnet used to spell words at a distance scratched down these words: "What hath God wrought!"

On page 132 is a reproduction of the very marks made by the first telegraph in sending this first telegram. They seem very rude and rough, yet they are full of interest as they show the finger marks of the first electro-magnet that wrote out a telegraphic message.

From the simple telegraph invented by Morse has grown up in these fifty years a vast and complicated system of transmitting and receiving messages. Yet in all the alterations and improvements the laws de-

monstrated by your experiments hold good. In every phase of the science there is the battery, the circuit, and the electro-magnet. The first great step in advance was the use of one wire instead of two. By inserting the ends of a single wire in the ground, connection is made with the great source of magnetism and electricity, the earth. The positive from the battery then flows through the line wire to the magnet and then seeks its negative in the earth. The positive of the earth in like manner flows up to the battery to meet its negative. The balance upset in the battery is restored and the polarities are satisfied precisely as if they met through a conductor forming a real circuit.

When a current of electricity passes through a conductor it is weakened, and, if the wire is too long, it may be so feeble that it cannot excite the electro-magnet. This weakening is said to be caused by the *resistance* of the wire. To compensate for this loss of power, at the distant end of a long wire a second battery and circuit is used and the electro-magnet is employed to open and close this second circuit. Such an arrangement is called a *relay,* and by the use of relays we are enabled to join circuit to circuit and thus send messages to great distances.

Improvements were rapidly made in the original Morse system. One of the most simple was the use of a

sounder, to enable the operator to read the message by sound instead of reading it from a recording apparatus. This sounder is merely a device for making an electro-magnet give out a loud click or beat each time it is moved, and its use reduced the receiving apparatus to the utmost simplicity.

It was in time learned that, by variations in the character of the current and the magnets, more than one message could be sent over one wire. For instance, one magnet might be sensitive to changes in the polarity of the current, while another might be sensitive to changes in the strength of the current only, and both would work over one line wire without interference. This idea in various forms led to duplex telegraphy. Other modifications led in time to the quadruplex system. More recently still, other changes that you could not understand without long study were introduced, and it is now possible to send many messages at one time over a single wire. Another great step was the invention of printing telegraphs that reproduced the actual words of the message sent over the wires. It was also discovered that if paper is wet with certain chemical solutions it is stained or discolored when an electric current is sent through it. This led to the chemical telegraphs, and by the use of certain machines it became possible to receive messages at a far more

rapid rate than they could be read on a sounder. Other improvements followed, and machines for transmitting messages were brought out. These *transmitters,* as they are called, made it possible to make and break the circuit many times a second. By combining the machine transmitters with the chemical recorders it is now perfectly easy to send many hundred words a minute over a single wire from Boston to New York.

Our first steps have led us to the threshold of a great science wherein you might spend a long life and not reach the end. We cannot understand it all now. You should go on to further study at some future time. We can now only glance at it in passing to recognize that under all the bewildering variety and complexity are the few simple laws demonstrated by your experiments.

In the telephone the electro-magnet is the basis of all the marvels of this wonderful invention. The sound of your voice is, in fact, a series of waves in the air. These beat on the armature of an electro-magnet and cause it to swing backward and forward in the field of the magnet. This slight movement causes delicate changes in the current in the coils of the magnet. These changes, corresponding in number to the sound waves started by your voice, travel over the line and affect another magnet, and cause its magnetic attraction to come and go in waves, now strong, now

weak. These variations in its magnetic field affect its armature, and it beats backward and forward and gives out to the air waves or pulsations that to the listener exactly resemble the sound of your voice. Again we see this wonderful tool called an electro-magnet performing an important part in the work of the world.

When a current flows along a large conductor nothing can be seen or felt to indicate its presence. If there is a break in the wire and the broken ends are close together, the current may leap across through the air in an arching stream of fire. This fact has been known for many years, yet it was not until within a very few years that any practical use was made of it. There were two reasons for this. The gap between the wires must always be the same. If it is too small the current passes in silence or with only a small flame; if too large it cannot pass at all. The arching flame to be of any value as a lamp requires very large and costly batteries. These two things kept this electric flame in the laboratory, and men thought of it only as a curious and expensive toy.

With the invention of the dynamo large currents of electricity were made possible. Then, after various trials with clock-work and other devices to control the conductors, inventors fell back on that old tool the electro-magnet. By its aid it was possible to make the

current itself regulate the gap between the conductors, and then the splendid arc-lamp came to fill our streets and shops with its brilliant light.

When a current traveling along a large conductor comes to a smaller conductor, it meets with resistance, and in its effort to overcome the resistance it heats the smaller wire. If the resistance is too strong the small wire may be heated white hot, perhaps be melted, or even completely burned up. This curious fact led to the invention of another form of electric light. By enclosing this smaller, high resistance part of a conductor in a glass globe or bulb and pumping out the air, the conductor would simply glow at a white heat without being melted. This led to the incandescent electric lamp. At first one form of dynamo was used for the flaming arc lamps, and another form for the glowing incandescent lamps. Now, by the use of a peculiar form of induction coil placed on an arc-light circuit, an alternating secondary current can be made to light the glow lamps. When we had to depend on batteries for electricity we were obliged to use copper and zinc in the battery, and those are costly metals. Even with large batteries we could only obtain comparatively small and feeble currents. Coal is cheaper than copper, and by burning coal under a boiler we can get steam that will move a steam engine,

and this can move a dynamo and give us electricity. It seems a roundabout road to use coal and water and steam in a boiler and engine and to employ a dynamo, and, yet all these combined are better and cheaper than a battery. We do several things to get one thing, but the result justifies the cost as the currents from the dynamo are larger, more powerful, and cheaper.

Naturally enough as soon as dynamos began to be made, people found many new and useful ways in which electricity could be used. The men of science in their laboratories knew of these things long ago. When the dynamo came these little laboratory experiments were transferred to the workshops and became of use to all the people. We may look at a few of these experiments that are now, or soon will be common things all about us in shops, in the streets, upon roads, on the farm and in our homes.

In melting the ores of iron to extract the pure iron out of the rough, red rocks found in the earth we build a huge structure called a "blast furnace," and fill it with the iron-stones and other materials and make a terrific white hot fire, from which flows the crude metal we call cast iron. There are certain substances that require an exceeding high temperature to extract the metals they contain. Such materials are said to be

"refractory." The arc light flame is intensely hot, and by the aid of a dynamo it is possible to extract these hard and refractory metals. It is true the flame of an arc light is very small. It would be useless in a blast furnace, yet in a small furnace and with a very costly metal like aluminium, it is useful and profitable.

For thousands of years blacksmiths have joined one piece of metal to another by heating them both and then, while they are soft, hammering them together. When they are cold they are firmly united in one piece. This work is called "welding." By the aid of the dynamo the blacksmith can now do his welding in a new and much neater and quicker way. He has two bars or two pipes he wishes to join together, and to get heat to soften the ends of the two pieces he has only to send a powerful current of electricity through both bars or pipes. On bringing the ends together the arc flame springs up and in its white heat the metal melts and grows soft. Then by pushing them together the two soft wax-like tips run together and on stopping the current they are found to be perfectly welded. Such work is called "electric welding" and it opens a new field in the blacksmiths' ancient art. So it happens that an electric current traversing in silence over a wire may come to take the place of the smoky forge

and the panting bellows. We may miss the glowing fire and the shower of sparks in the old shop by the roadside, yet we see it is far better that the work be done quickly, neatly and silently in a clean, bright workroom, better for the work and better for the workman.

We have seen the tinsmith and the plumber in their shops busy soldering together sheet tin to make pails or dippers or joining lead pipes for water in our homes. Each has a little fire in which he heats his "soldering iron" that he may melt the soft alloys called "solder" and make our pails or pipes water tight. Now these workmen can put out their little charcoal fires and use a soldering iron kept hot by means of an electric current that flows through a wire fastened to the handle of the tool. It is possible to even go further and to heat an oven by electricity, and use the current from a dynamo to bake a "tea biscuit" or a loaf of bread." Thus in small fine work where an intense heat is required by the blacksmith, the tinman, the plumber and jeweler, the dynamo is coming to take the place of coal and other fuels in stoves and furnaces.

When dynamos began to be used it was soon found that there was still another use for electricity. The dynamo being an inductive machine it is easy to see

that its current might be used to produce magnetism. It was found that if the current from a dynamo was led through a wire to a second dynamo that magnetism was produced in it—and under its influence the second dynamo would move. By thus joining one dynamo to another we were enabled to *transmit power.* For instance, a steam engine is giving its power to a dynamo and it is, in turn, giving out electricity. We take this current over a wire to a distant place, say a mile or more away, and find it will cause the second dynamo to move swiftly. Clearly the motion or power of the steam engine reappears as motion or power in this second dynamo, and we have practically carried power from one place to another. This is perhaps the most remarkable result that has come from the invention of the dynamo, and it is difficult to imagine the great and wonderful changes that may flow from this transmission of power.

We visit a factory and see a number of girls at work with sewing machines. We notice that each machine is moved by a belt from a shaft on the floor or overhead near the ceiling. It would not pay to ask each girl to run her own machine, and it is cheaper to have a steam engine in the cellar. The motion of the engine is carried by belts, wheels and shafting to each machine to do the heavy work and leave the girls free

to guide the cloth to the needles. It may be the factory is near a river and a water-wheel is used instead of an engine. In either case belts and shafting must be used to convey the power to the machines, and the factory must be very near the engine or the water-power.

Now, if a dynamo is used, the engine or the turbine (water-wheel) may move the dynamo to give electricity, and the current may be carried to the second dynamo or "motor," and this motor may drive the sewing machines. The current may be divided up and each girl may have a little motor to drive her machine. The factory need not be near the water-power or the engine house, for the wire may carry the current to another place. Besides this, a wire is smaller and lighter than belts and shafting, and the building used for a factory need not be so strong and therefore not so costly. The walls and the floors may be lighter, and there may be more windows, and thus the girls will work in a cooler, safer, more comfortable and more healthful place, far away from the noisy, dusty and ill-smelling steam engine and boiler, and far away from the dampness and chill of a waterfall.

More curious than all, a current from an engine may be sent over a wire and we may take off a part of this current at any time and while moving along the

wire. We see this in the electric railroads. The motor is under the car and the current comes down to it from a little wheel traveling along the wire. It is not easy to see what will be the future of this curious method of transmitting motion to a car traveling along a railroad. We see already electric railroads increasing every year, and we learn that inventors are at work perfecting plans for sending letters and small packages to great distances across the country and at very high speed. Whether we shall ride a hundred miles an hour or not is doubtful. It would be a rather breathless speed and might be very uncomfortable, yet it is quite possible our mail bags will fly on wires over the country at very great speeds. Already we may see buckets and baskets travel along wires suspended from poles and carrying sand, iron ore, stones and other loose freight from place to place by means of electric motors.

It has been known for some time that a current of electricity will cause films of metal to be deposited upon objects suspended in liquids containing these metals. This we recognize as the useful art of plating. We see the silver plater cover metal knives, forks and spoons with a thin film of pure silver. We see the electro-plater cover the printer's types and the engraver's blocks with thin films of copper and then

filling these skins of copper, that are exact copies of the type or block, with lead, give them to the printer for use in his press. We see the jeweler plate his decorative work with silver, copper and gold, and we are glad to use the beautiful work for ornaments and decorations. With the introduction of the dynamo this art of electro-depositing or electro-plating was greatly improved. With stronger currents it became possible to plate larger objects, such as the wires used for telephones, statuary, architectural ornaments, water, steam and gas pipes. Copper pipes are made by rolling up sheets of copper and welding the laps or edges together. By the use of electricity it is now possible to make pipes by electro-deposition. A cylinder of wax or other material that may be easily melted is plated with copper, and the center or "core" is melted out and thus giving a pipe exactly alike inside and out in one beautiful hollow cylinder without flaw or crack, literally a pipe made without hands.

In all these wonderful changes that have followed the introduction of the dynamo you notice there is always, behind all, the steam engine or some other "prime mover" or source of power. It seems now as if power were really the most valuable thing in the world. It gives us light and heat, and enables us to control power at a distance and to transmit power to a

distance. Naturally we look about to see where the power is to come from to do all this electrical work. First of all are the fuels, coal, gas, oil and wood. Coal we can dig out of the ground, natural gas and oil flow out of the earth and wood grows in the forests. These are our supplies of power-makers, because they can be burned to make steam and steam means power. Besides these fuels we have gravity or weight, and the moon and the sun to help us. Water falling over a cliff or dam will give us power. The moon controls the tide and the tide can be used to drive our water-wheels. The sun heats the air and causes the wind to blow, and the wind may turn a windmill to drive a dynamo. So far, we use chiefly coal, gas and wood and sometimes oil to make steam, and we set up our turbines at every waterfall to get power from the falling water. The winds and the tides we use very little for power. Our fuels may some day be all burned up, just as we are really burning up all our natural gas and do not know where to look for more. Then we shall use more water-power and shall learn to harness the tides and the winds. These will never fail while the big star on which we live moves round the sun, and while the seas remain. The sun moves the wind and brings us the rain in our rivers and the tides obey the moon. In short, it is really the sun

that does all, that prepared the coal and supplies every river with water and stirs every breath of wind. The sun is therefore our source of power. Power we shall need more and more, and so long as our little star, the earth, swings round the big star, the sun, so long shall we have power.

"Fire is a good servant, but a bad master." It is useful in the stove, and very destructive when it gets hold of the house. So water may be fine for skating or boating and dangerous if we happen to sink in it. In like manner electricity is useful in its wire and terrible in the lightning flash. The current from a dynamo may kill a man, just as fire may burn him or water drown him. We recognize the danger and avoid it. The great danger of electric currents lies wholly in a want of insulation. All wires conveying large and powerful currents must be insulated. If bare, as in the wire used for electric railroads, we must simply keep away from it. Safety lies in knowledge, in carefulness, in proper insulation, in good work. We must master electricity and never let it master us.

These first steps in electricity bring us to a most interesting point in the history of this great science. Many of the inventions that have made the laws of electricity useful in the world have been brought out within the memory of people now living. The dynamo

that has made the production of powerful currents of electricity both easy and cheap, is hardly twenty years old. The telephone is so new that the first patent on its construction has not yet expired. New electrical inventions appear every year and we may take up the newspaper some morning, just as we all did last summer, and read an account of a new electrical invention or new use for electricity that may be as valuable as any that we have seen. Even now men of science all over the world are experimenting with this mysterious force in the hope of finding new ways in which it may be of benefit to men, women and little children. Active and curious minds are everywhere, and particularly in this country, asking questions of nature that we may better know her laws and be enabled to use them in new and useful ways.

Among the new electrical problems men are trying to solve two seem to promise great and important results. When a battery is at work there is a chemical action going on between the acid and the two metals. The result of this action is an electrical current. It has been discovered that, if a current from a strong battery or from a dynamo is sent into a battery this chemical action may be reversed. The chemical changes produced in making the first current will, as it were, be turned round and made to go the other

way against its will. When this stronger current stops, the chemical action will reverse or go back again and give out an electric current. The most curious part of this action is that the new electric current will be stronger than the first current from the battery itself. It is very much as if a quantity of electricity had been poured into the battery and bottled up for future use. Batteries arranged in a certain way may thus become storage places for electricity. Not really, but in a way that produces the same effect as if the current had actually been stored or kept in the battery. The current is sent into one of these storage batteries. A chemical change takes place under the influence of this current. Then, at any time afterward (within certain limits), this chemical change can be used to send out a new current almost as strong as the current sent into the battery.

The storage battery, with its chemical change ready to begin instantly at any time to send out a current, can then be carried anywhere to light a lamp or move an electric motor. A storage battery when *charged* may be put in a boat and its current in *discharging* may turn the boat's propeller and move it through the water, and at the same time light the red and green lamps at the bow of the boat. A storage battery may be put on a horse-car and move it through the streets and keep it

lighted at night, or may be put on a train of cars and light the sleepers all night while the train goes from Boston to New York. These storage batteries have been greatly improved within the past few years and are coming into daily use all about us both for light and for power.

When the first telephones were used there was a great deal of trouble from induction. The telephone wires placed on poles beside the telegraph wires were subject to induction every time there was a make or break in the line wires near them. In the telephone wire there was a pulse of induced current at each dot and dash of the messages in the line wires, and this induced current produced curious sounds in the telephone that interfered with the words spoken in it. This induction is always more or less active in all telephones and manifests itself by the curious crackling and spattering sounds you sometimes hear when the receiver is at your ear. This induction, that when the telephone was new seemed to be so troublesome, is now used in telegraphy. By its use it is now possible to telegraph from a moving train of cars on a railroad to any and all stations along the road. The idea underlying this singular invention is the use of a telephone to listen to the sounds made by induction from a wire beside the track. This road wire produces, by induction

through the air to the train, a curious buzzing sound in the telephone on the moving cars. Every stop and start in this continuous sound in the phone may spell the words of a message sent through the wire. This, in a very few words, is the underlying idea of this most useful invention. By its use accidents can be prevented on the railroad, because the conductor can be informed, even while flying along at fifty miles an hour, of the position of every train before or behind him, and the condition of every bridge and switch along the way.

These marvelous inventions appeared only a few months since. Others as curious and useful may appear to-morrow. We live in a time of scientific discovery and advance. Old experiments appear as daily conveniences. Familiar laws find new applications and old inventions are made more simple and of wider usefulness. Inventors, men of science, men of business who see the value of ideas, facts, and laws—all are busy experimenting, perfecting, and making useful these marvels of electricity.

We read with wonder of the doings of the great men mentioned in history: Frederick the Great, Napoleon, great kings and generals. We should remember that to-day, in our own streets, are men who are doing more good than kings, emperors, or generals, because they are subduing nature and opening the kingdom of

science to all. Some of these men who live among us may leave names that will be remembered long after kings and emperors have been forgotten. Being a king is a pretty selfish business at best. It has meant, in the past, war, trouble and misery for the people, and hatred for a memory. The worker in science, the inventor who makes the laws of nature useful, leaves no armies of widows behind him, no ruined cities for a monument. His work lives after him because, by his labors, life is more easy, more comfortable and pleasant. All the people lead happier lives because he lived.

This is the end of all steps in science. We have taken only a few. We might go on for years and find that all true and honest work in science leads to doing good. Best of all, this very work is now of great benefit to the inventor himself, for whoso discovers or invents a new thing of use to all men, will, unless he be blind or foolish, reap a great reward, both in wealth and in the respect and admiration of his fellow men. Every step in science, every effort we make to learn, however small and slow the pace, is attended by a sure reward. It depends upon ourselves what and how great the reward shall be. We may not find the reward in dollars, yet we shall find something if we be only earnest, patient, and ready to learn. Moreover, let us not think all is

known, let us not imagine, in the midst of the wonders of science and invention we see to-day, that there will be no more discoveries, no new experiments and inventions. Every one of us, if we be earnest to learn, may be a discoverer of new truths and new facts. At any rate, we can all of us find by experiments facts that will have all the freshness and novelty of discoveries, because learned for ourselves directly from the great school-book we call nature.

So this strange agent, this thing we call electricity, has come into all our lives, another gift from the Creator. We rub silk on glass and electricity manifests itself. There is motion and electricity. We know there is also heat, because the glass feels warm to the hand. We see coal put under the steam-boiler, and there is heat from the fire. This heat gives steam from the water, and in the steam-engine this gives us motion. This motion moves the armature of a dynamo, and we have electricity. The current of electricity in the electric lamp gives heat again, and from heat we have light. We burn a certain quantity of gas in a lamp and get heat and light. We burn the same amount of gas in a gas stove and get more heat and much less light. We burn the same amount of gas in a gas engine, and we get heat and motion without light. We use this motion from the gas engine to move a dy-

namo and produce electricity, and in electric lamps we get light and heat. Now do all things work together for good. We wonder if there is any difference between light and heat and motion. Men who have studied these things tell us they are the same, that heat is a mode of motion, that light is excessive heat which is only excessive motion. Motion becomes, through electricity, light; heat becomes motion; and light is motion. Thus, one thought joins all the circle of the sciences together. That which appeals to the eye is only another form of that we feel in heat. Motion appeals to the ear as sound, to the eye as light, till we wonder if there be anything save motion. These are the suggestions of the relations of the sciences brought to us by this agent called electricity, which seems to be a part of all and controlled by all. It certainly springs from heat and motion, and it will manifest itself as heat and light which are phases of motion. We begin to apprehend that the Creator's thought is as one thought, that there is a unity in nature far beyond anything our fathers imagined.

Moreover, this unity of motion—electricity, magnetism, heat, light, and sound, we see in our telegraphs, telephones, and electric lights—extends far beyond our little world. The sun is over ninety millions of miles away, and yet we know that electrical disturbances in

the sun may affect every telegraph on our globe. The laws that the Creator implanted in things here are the same in the sun and in the entire solar system. We can go farther still and yet fail to get beyond the reach of law. The laws demonstrated by your little experiments in these our first steps hold good along the paths of suns whose light is as star-dust on the midnight sky.

THE FIRST TELEGRAM.

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